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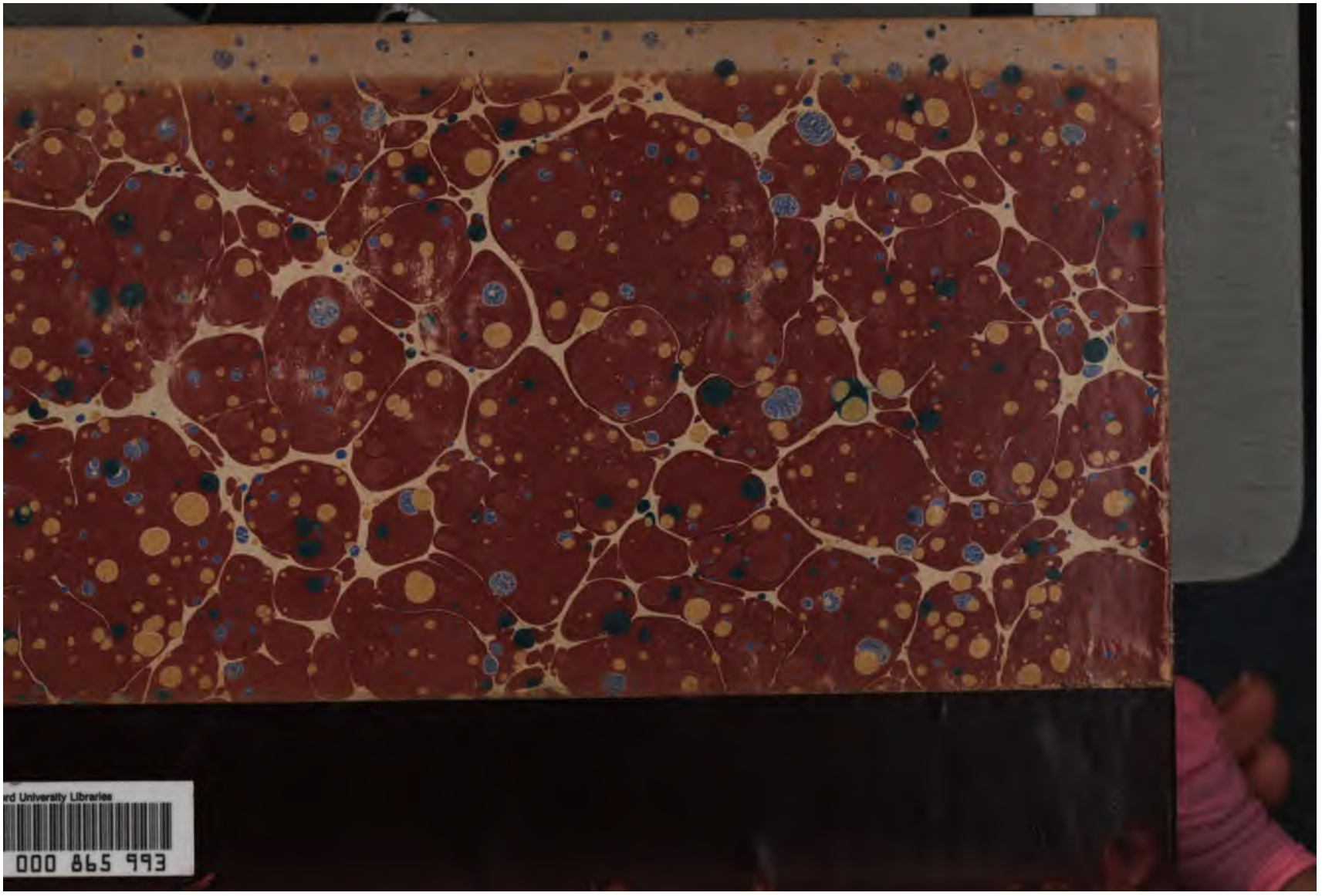
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Lisbon (Tapada), Portugal. Real Observatorio.
London, England. British Astronomical Association, care of F. W. Levander, 30 North Villas, Camden Square, N. W.
London, England, British Museum.
London, England, Royal Astronomical Society.
London, England, 3 Verulam Bldgs., Gray's Inn, The Nautical Almanac.
Lund, Sweden, University Observatory.
Madison, Wisconsin, Washburn Observatory.
Madrid, Spain, Royal Observatory.
Marseilles, France, Observatoire.
Melbourne, Victoria, Observatory.
Mexico, Mexico, Sociedad Cientifica "Antonio Alzate."
Milan, Italy, Royal Observatory.
Moscow, Russia, University Observatory.
Mount Wilson, via Pasadena, Cal., Solar Observatory.
Munich, Germany, Königliche Sternwarte.
Naples, Italy, Royal Observatory.
New Haven, Connecticut, Yale University Observatory.
New York, New York, American Mathematical Society.

New York, New York, Columbia University Observatory.
Nice, France, Observatoire.
Northfield, Minnesota, Goodsell Observatory.
Oxford, England, Radcliffe Observatory.
Oxford, England, University Observatory.
Padua, Italy, Astronomical Observatory.
Paris, France, Bureau des Longitudes.
Paris, France, Observatoire National.
Paris, France, Rue Cassini 16, Société Astronomique de France.
Philadelphia, Pa., 105 South Fifth St., American Philosophical Society.
Potsdam, Germany, Astrophysikalisches Observatorium.
Prague, Austro-Hungary, Universitäts-Sternwarte.
Pulkowa, Russia, Imperial Observatory.
Rio de Janeiro, Brazil, Observatory.
Rome, Italy, Observatory of the Roman College.
Rome, Italy, Specula Vaticana.
San Francisco, California, California Academy of Sciences.
San Francisco, California, Technical Society of the Pacific Coast.
Stockholm, Sweden, University Observatory.
Strassburg, Germany, Universitäts-Sternwarte.
Sydney, New South Wales, Observatory.
Tacubaya, Mexico, Observatorio Astronomico Nacional.
Tokio, Japan, University Observatory.
Toronto, Canada, Astronomical and Physical Society of Toronto.
Toulouse, France, Observatoire.
Turin, Italy, Observatory.
University Park, Colorado, Chamberlin Observatory.
University of Virginia, Virginia, McCormick Observatory.
Upsala, Sweden, University Observatory.
Vienna, Austria, Imperial Observatory.
Vienna (Ottakring), Austria, Von Kuffnersche Sternwarte.
Washington, District of Columbia, Library of Congress.
Washington, District of Columbia, National Academy of Sciences.
Washington, District of Columbia, Naval Observatory.
Washington, District of Columbia, Smithsonian Institution.
Washington, District of Columbia, The American Ephemeris.
Washington, District of Columbia, U. S. Coast and Geodetic Survey.
Williams Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

EXCHANGES.

Astrophysical Journal, Williams Bay, Wisconsin.
Prof. Dr. H. J. Klein, Editor of *Sirius,* Theresien St. 85, Köln-Lindenthal, Germany.
The Observatory, Greenwich, England.

FOR REVIEW.

[See *Publications*, A. S. P., Vol. VIII, p. 101.]

The Call, San Francisco, California.
The Chronicle, San Francisco, California.
The Examiner, San Francisco, California.
The Mercury, San José, California.
The Record-Union, Sacramento, California.
The Times, Los Angeles, California.
The Tribune, Oakland, California.

THE SOLAR CORONA
AUGUST 30, 1905
CROCKER ECLIPSE EXPEDITION
ALHAMA. SPAIN

THE LICK OBSERVATORY–CROCKER ECLIPSE EXPEDITION TO SPAIN.

By W. W. Campbell and C. D. Perrine.

The total solar eclipse of August 30, 1905, was looked forward to with unusual interest. Its duration,—three and three-fourths minutes as a maximum,—its occurrence at the season of the year when weather conditions would be the most promising, and the ease of access to widely separated observing stations on three continents, formed a favorable combination of rare occurrence. The eclipse would occur in Spain an hour and a half later than in Labrador; and in Egypt an hour later than in Spain. Here were offered just the opportunities desired to determine the existence and perhaps the character of motions within the coronal structure, and to search for possible intramercurial planets. To take suitable advantage of these rare opportunities required that well-equipped expeditions, working in harmony and co-operation, should be sent to each of the three countries mentioned. The subject was brought to the attention of Mr. William H. Crocker in July, 1904, who was quick to recognize the scientific importance of the event; and he at once made provision for meeting the expenses of the three large expeditions, as planned.[1] Preparation of the apparatus commenced at once and continued uninterruptedly until June, 1905.

With the approval of the Board of Regents of the University, the Labrador expedition[2] was dispatched in charge of Acting Astronomer Heber D. Curtis; the Spanish expedition in charge of Director Campbell, with Astronomer C. D. Perrine as associate; and the Egyptian expedition in charge of Astronomer W. J. Hussey.[3]

The path of totality, about one hundred and twenty miles wide, crossed northern Spain in a northwest-southeast direction. The cities of Oviedo, Burgos, Soria, and Daroca are

[1] Mr. Crocker's generosity in sending eclipse expeditions from the Lick Observatory, University of California, to Georgia in 1900, to Sumatra in 1901, and to Labrador, Spain, and Egypt in 1905, is recognized wherever astronomical literature travels.

[2] Dr. Curtis's account of this expedition was published in these *Publications*, No. 105.

[3] Astronomer Hussey's report follows in the present number of these *Publications*.

a few miles north of the center line of the path. Logroño and Zaragoza are a few miles within the northern edge of the shadow, and La Coruña and Valladolid are a few miles within its southern edge. Valencia appears to be located almost exactly on the southern edge. Excellent maps of the eclipse path, on both large and small scales, prepared by the Madrid Observatory and published by the Spanish Government, were very useful to observers in deciding upon their observing stations. Director IÑIGUEZ, of the Madrid Observatory, kindly placed at the disposal of observers a considerable quantity of meteorological data, notably the observations for 1897 and 1898, in order that they might judge of the weather probabilities. The best promise for a large number of clear days, small rainfall, low humidity, and small diurnal range of temperature seemed to be afforded by the region south and southwest of Zaragoza. Burgos, with slightly poorer weather conditions, as shown by the records, was to be the destination of numerous expeditions, as well as the objective point of the tourists,—good and sufficient reasons for our avoidance of it. A consideration of all the conditions, several months before leaving Mt. Hamilton, led to the decision that the expedition should locate in the Almazan-Ateca-Daroca region.

The scientific apparatus and supplies for the three expeditions were packed on the first three days of June for shipment by wagon to San Jose, thence by railway to Galveston and Gulf steamer to New York.

Mr. and Mrs. CAMPBELL, Mr. and Mrs. PERRINE, and Volunteer Observer THOMAS E. MCKINNEY, Professor of Mathematics and Astronomy in Marietta College, Ohio, sailed f om New York on July 6th, per White Star steamer "Romanic," bound for the Azores, Gibraltar, Naples, and Genoa. The freight for the Spanish and Egyptian expeditions was on the same ship. The passage was an especially favorable one, as there was neither wind nor wave until the day before reaching Gibraltar. Nevertheless, the steamer's schedule was not maintained. The arrival at Gibraltar was a day late, which caused only minor inconveniences; but the delay in reaching Genoa was more serious in its consequences.

Mr. and Mrs. CAMPBELL disembarked at Gibraltar and journeyed overland to make necessary official arrangements

at Madrid, to select and prepare the site for the observing station, and to provide living accommodations. They stopped a day at Granada to see the Alhambra and other historical and architectural interests of this city, but, with eclipse duties ahead of them, they were in no mood for sightseeing. The other members of the expedition continued on the same ship, first to Naples, where Professor HUSSEY received in person the Egyptian freight, and thence to Genoa, where transfer to a steamer sailing direct to Barcelona was to be made. Unfortunately the belated arrival at Genoa vitiated the arrangements kindly made by the American Consul for a quick transfer to the Barcelona steamer, for which there should have been abundant time. This failure to make connections involved a delay of one week at Genoa, a loss that could ill be afforded at the observing station. Passage was secured on the steamer "Jativa," leaving Genoa on July 27th and reaching Barcelona on Saturday evening, July 29th.

The freight having been seen on board a railway car, Mr. and Mrs. PERRINE proceeded to the eclipse station, arriving on August 2d. Dr. MCKINNEY traveled on the train which carried the instruments, keeping watch on the eclipse car to guard against delays. He brought the car to its destination on the morning of August 3d.

The main line of railway from Madrid to Zaragoza crossed the central line of the shadow-belt at the village of Alhama, in Aragon. This place is justly famous for its wonderful springs of warm water. Its baths were known to and patronized by the Romans in the days of the Roman occupation, and they continue to be used extensively in the late summer months by the Spaniards, for rheumatic and other complaints.

Interviews in Madrid with Professor CASARES, Astronomer IÑIGUEZ, and others led to the provisional selection of Alhama for the observing station. The weather indications seemed to be as promising there as anywhere along the line; no other expedition was planning to locate in Alhama; it was the point of easiest access for the imported instruments and for daily supplies, as well as for the assistants who were to come from Madrid, Zaragoza, and northern Europe; and there was a hotel with which arrangements for accommodations could be made. The latter point was of considerable importance, as

there were to be about twenty-five members of the expedition during eclipse week; and while food supplies in abundance had been taken from New York, in case it was necessary to establish our own camp, we were soon convinced that this should be avoided at almost any cost.

Mr. and Mrs. CAMPBELL reached Alhama on July 21st. This village of fifteen hundred people has an interesting location from the geological point of view. It is in a valley bounded for the most part by steep and conspicuously stratified walls of rock from two hundred to four hundred feet high. Near the center of the village these walls approach each other quite closely, so that the form of the town is roughly that of an hour-glass, whose length lies southwest and northeast. The fertile floor of the valley is subject to severe floods, and could not be thought of in connection with a site for observations. After careful search of the surrounding country, a satisfactory location was found near the southernmost part of the village, on a small hill rising about sixty feet above the valley. Some forty years ago a *palacio real* had been built, an artificial lake constructed, and the surrounding grounds improved to supply accommodations for the King, who was coming to take the baths. The hill referred to is in the palace grounds. It is fairly well covered with pine trees, especially on the slopes lying below the lines of sight of the instruments at the time of the eclipse. It is easy of access and, equally important, easily closed to inquisitive visitors. It was therefore definitely decided, on July 24th, to locate here. A half-dozen large rooms in a thick-walled masonry house, perfectly adapted to mechanical and photographic work, were found near the foot of the hill. Satisfactory arrangements were made with Hotel Los Termas for the accommodation of the party. During the following nine days, while waiting for the other members of the expedition to arrive with the instruments, laborers were employed in repairing the road to the summit, making the excavations, constructing the brick piers, and providing for the water and other supplies.

These preliminaries having been arranged, the assembling, mounting, adjusting, and testing of the instruments proceeded rapidly from the date of their arrival. We were fortunate in having the assistance of Dr. MCKINNEY and Dr. R. S. DUGAN,

THE OBSERVERS, ALHAMA, SPAIN.

formerly Assistant in the Heidelberg Observatory and now of Princeton University, throughout the entire period of work, from unpacking to repacking. Professors SVANTE ARRHENIUS and GUSTAF KOBB, of Stockholm University, were with us for ten days following August 20th. Mr. C. M. OLMSTED, an American student in Bonn University, was with us from August 25th to September 1st, and Mr. FREDERICK PALMER, Jr., of Haverford College, from August 27th to September 3d. To these six gentlemen the expedition is under special obligations. Even with their skillful assistance the work of preparation was exceedingly strenuous. We were able to obtain excellent unskilled laborers, but we found it expedient to be our own carpenters and machinists.

The available weather records for past years gave promise of very light rainfalls in the months of July and August. This promise was realized in August, but not in July. From July 21st to August 2d there were six heavy rainstorms, and the fall probably amounted to seven or eight inches. These storms were reported to be of wide extent in northeastern Spain, causing serious floods in many quarters. During the period August 2d to September 1st the weather conditions were excellent for erecting and testing the apparatus. There were sprinkles or slight showers on August 4th, 10th, 23d, and 25th, which caused no damage and little inconvenience. Nearly all the nights and forenoons were clear. The majority of the afternoons were clear, but there was a marked tendency for thin clouds to form in the early afternoon. On many days the sky was beautifully blue and markedly free from glare around the Sun. The Milky Way frequently shone as we have seldom seen it except on Mt. Hamilton.

The other volunteer assistants who were to take part in the observations arrived at Alhama on August 27th and in the morning of August 28th. They were: Professor Dr. J. HARTMANN, Astrophysical Observatory, Potsdam; Sr. D. ERNESTO GREVE, National Observatory, Santiago, Chile; Dr. VIGGO STRÖYBERG, formerly in the observatory, Copenhagen; Sr. D. ARTURO CUYÁS, Madrid; Professor JOSÉ CASARES, Central University, Madrid; Professor HILARIÓN GIMENO, University of Zaragoza; Professor ANTONIO ROCASOLANO, University of Zaragoza; Professor FELIPE LAVILLA, University

of Valencia; Lieutenant MANUEL HERNANDEZ, Geodetic Survey, Madrid; Sr. D. ESTEBAN TERRADAS, University of Madrid; Sr. D. ENRIQUE IBAÑEZ, Secretario de Municipalidad, Alhama; Sr. D. FELIPE HERREROS, Telegraphico, Alhama; Sergeant ESTEBAN BARBAJOSSA, Guardia Civil de Espagna; Sr. JUAN BLASCO, Guardia Civil de Espagna.

The remaining days were devoted to training the twenty-four observers to their duties at the instruments, to testing the final adjustments, to preparing the photographic plates and their holders, and to arranging the multitude of details which affect success.

Threatening weather conditions arose on the evening of the 28th. From early morning of the 29th until late in the afternoon the wind blew a veritable gale and the sky was thickly clouded. Although the ground at the station was thoroughly sprinkled, the wind brought clouds of dust from a distance. The rehearsals of programme were made very difficult, and the situation was discouraging. However, the wind ceased and the sky cleared in the early evening.

The night of the 29th and the forenoon of the 30th were as perfect as any during our stay in Alhama. About noon of the 30th clouds began to form here and there; by 12:30 they were numerous, especially in the northwest; and before 1:00 a sheet of light mackerel clouds was streaming southeasterly across the Sun. During totality,—from 1:11 to 1:15, Greenwich mean time,—the principal prominences and the general features of the corona were visible through the thin clouds. The clouds probably permitted from twenty to thirty per cent of the photographic rays to pass. The lower atmosphere was perfectly calm; not a breath of air was stirring.

All preparations were completed, and the observers were in their places, several minutes before totality began. Signals "5 minutes," "1 minute," and "20 seconds" were given by Mr. OLMSTED at the timepiece. Certain of the spectrographic exposures were to begin at "12 seconds" before the computed time of total eclipse. Totality began about 17 seconds earlier than the computed time, on which account the few affected spectroscopic exposures were necessarily omitted; but all the exposures after the beginning of totality were secured as planned.

Much has been tried for at this eclipse, and the presence of clouds was a severe discouragement. Nevertheless, considerable confidence was felt that sufficient light had penetrated the clouds to give useful results with most and perhaps all of the eighteen instruments. Development of the plates on succeeding days showed that the coronal photographs were most excellent,—the "seeing" had been good; that nearly all the spectrograms were of splendid quality; but that the intramercurial plates and those spectrograms which demanded all the light from an unclouded sky were only partially successful.

Mathematical astronomers have made comparatively little use of eclipse contact-time observations for improving our knowledge of the Moon's motion. The expense and time involved in transporting, erecting, and using meridian instruments for the purposes of the three expeditions seemed unjustified, and it was accordingly decided to depend upon sextant observations of the Sun, not only for time, but for latitude determinations also. In Labrador the eclipse-path lay due east and west, and a knowledge of the *longitude* was an unimportant consideration so far as selecting a station was concerned. It was known that His Excellency, Governor McGregor of Newfoundland, a geodesist of considerable experience, was to make a latitude and longitude expedition to the eclipse stations[1] in the month of August. From the large-scale maps of the Aswan district, kindly sent to the Lick Observatory by Captain H. G. Lyons, R. E., Director-General of the Egyptian Survey, it was also evident that the latitude and longitude could with confidence be taken directly from the charts. The transportation of chronometers on long railway journeys is attended with considerable risk, and it was thought that good watches would be satisfactory substitutes. Through the kind offices of Mr. F. H. McConnell, of San Francisco, eleven watches were sent to Mt. Hamilton late in 1904 for trial. Three Elgin watches were selected, whose performance compared very favorably with that of standard chronometers when they were handled with the same care that chronometers demand. One of these watches was sent with each expedition.

It is probable that observations of the Sun, secured with

[1] For an account of his work at the Lick Observatory-Crocker station in Labrador, see these *Publications*, No. 105, p. 178.

sextant and watch, before and after the eclipse, furnish time for the eclipse as accurately as observations with transit and chronometer made on the stars during the preceding and following night, especially if there are considerable changes in temperature from night to day and day to night.

When Mr. CAMPBELL was in Madrid he arranged with Director IÑIGUEZ to send electric time-signals from the standard clock of the Madrid Observatory to the eclipse station. Through the kindness of the telegraphic service these signals were received satisfactorily on several dates between August 3d and August 16th, inclusive. The longitude as obtained from these signals and the local time observations, the latitude obtained from circum-meridian altitudes of the Sun, and the altitude above sea based upon the figures published for the railway at Alhama, are

Longitude $= 7^m\ 36^s = 1°\ 54'\ 00''$ W. of Greenwich.
Latitude $= +41°\ 17'\ 40''$.
Altitude $= 2{,}200$ feet $= 670$ meters.

The station was almost exactly on the central line of the shadow.

The computed times of beginning and ending of totality, based upon American Ephemeris data, determined by Messrs. KOBB, OLMSTED, and CAMPBELL, were

II, $1^h\ 11^m\ 23^s$, Greenwich M. T.
III, 1 15 08 " "

The signal that totality was complete was given by Mr. PERRINE, based upon naked-eye observation, at $1^h\ 11^m\ 07^s$, Greenwich mean time. Dr. DUGAN, who was observing the diminishing crescent on the plate-holder of the 40-foot camera, estimated that totality occurred between one and two seconds earlier. We think it is entirely possible that the very bright prominence near the point of second contact may have influenced the naked-eye observation, and $1^h\ 11^m\ 06^s$ is perhaps the time to be adopted. The Sun reappeared at $1^h\ 14^m\ 45^s$. The duration was therefore $3^m\ 39^s$, or six seconds less than that given by the American Ephemeris. Totality began 17 seconds earlier and ended 23 seconds earlier than the predicted times. The middle of the eclipse thus occurred 20 seconds earlier than expected. There seems to be no escaping the fact that the

Moon was far ahead of its predicted right ascension. Time-signals received on six days directly from the Madrid Observatory made a serious discrepancy in the adopted longitude impossible, and it agrees exactly with that read off from the excellent large scale map of the Province of Zaragoza prepared by the Geographical Engineers, and presented to us by the Government of Zaragoza. Very accordant sextant observations for time had been secured at 8:10 A. M., 10:40 A. M., and 3:10 P. M. of the eclipse day, and this element could not be in error by as much as one second.[1]

This was a "dark" eclipse, notwithstanding the light diffused by the clouds. It was very much darker than those of India, 1898, and Georgia, 1900, and darker than that of 1901 in Sumatra. The amount of cloudiness at the two stations in 1901 and 1905 was not very different. At the former eclipse Mr. PERRINE could read the figures in a table of logarithms easily, while at the latter he had to look closely to distinguish them.

The eighteen instruments of observation were mounted in six groups, each group depending upon one driving-clock. The six groups were so situated that all the observers could hear the time-counter, who occupied a central position with reference to them.

TIME SIGNALS.

In charge of Mr. CHARLES M. OLMSTED.

Each of the three expeditions was provided with a pendulum, consisting of a rod and a heavy flat lead disk, which could be adjusted to one-second period. The Spanish pendulum, supported by a stout bracket on a heavy timber post, was set in motion shortly before totality. Beginning with the swing following the signal for totality, Mr. OLMSTED counted "One, two, three, four, . . ." until, after the reappearance of the Sun, the pendulum counts had been compared twice with the watch and recorded. This method was entirely satisfactory.

FORTY-FOOT CAMERA.

In charge of Dr. DUGAN, assisted by Professor LAVILLA.

The outside general features of this instrument, designed by Professor SCHAEBERLE for observing the eclipse of 1893,

[1] After this was written, a number of preliminary eclipse accounts of other expeditions have come to hand, and many of them noted that totality occurred some twenty seconds earlier than predicted.

are shown in the reproduced photograph of the station. In this camera the Clark lens of 5-inch aperture, the combination tube of iron and cloth, and the plate-carriage moving by clockwork on an accurately curved metal track, are supported entirely independently of each other. The lens is mounted on the top of a strong interior tower, surrounded by a cloth-covered outer tower, whose duties are to support the upper end of the camera tube and to prevent the wind from shaking the inner tower; a system of lens support devised by Mr. CAMPBELL to meet conditions on the plains of India in 1898. With this form of support the camera can easily be pointed near the zenith if necessary (as in Sumatra by Mr. PERRINE in 1901); and the advantage of having the lens at a good height above the radiating soil is preserved. The towers are easily constructed, the various parts of the camera are quickly put into their approximate positions from simple computations, and the final adjustments are readily made.

The Sun's altitude at Alhama was 55°, and the center of the lens was 32 feet 8 inches = 9.96 meters above the center of the photographic plate.

Ten exposures were made on Seed No. 27 plates, as follows:—

No. 1,	½	second,	before	count	"one"			
2,	1	"	from	0^m	07^s	to	0^m	08^s
3,	4	"	"	0	14	"	0	18
4,	8	"	"	0	24	"	0	32
5,	64	"	"	0	44	"	1	48
6,	64	"	"	1	58	"	3	02
7,	8	"	"	3	12	"	3	20
8,	2	"	"	3	25	"	3	27
9,	1	"	"	3	35	"	3	36
10,	½	"	"	3	41	"	3	41½

The two 64-second exposures were on plates 18 × 22 inches, and the other exposures on plates 14 × 17 inches. Plates Nos. 4, 5, and 9 had "standard square" exposures made near one corner of each of them at Mt. Hamilton in May by means of a Hefner amyl-acetate lamp, kindly loaned for the purpose by the Department of Physics of the University of California.

GENERAL VIEW OF THE LICK OBSERVATORY-CROCKER ECLIPSE EXPEDITION, ALHAMA, SPAIN.

These squares are intended as a basis for a photometric study of the coronal images.

When the negatives were developed we were relieved to find that the clouds had exerted no bad effects upon their quality: the obscuration had simply reduced the effective coronal intensity without spoiling the definition. The "seeing" had been good, and the negatives were of great excellence. The longer coronal streamers were recorded out to about one solar diameter from the Sun's edge. The details of the great prominences on the eastern limb, of a few of the smaller prominences, of the coronal arches over the prominences, and of the coronal structure are of great interest. The streamers were, in general, of substantially equal lengths at all points of the solar limb. Those of more than average lengths seemed not to be specially related to the great streamers visible at times of sun-spot minima. The present corona was a "maximum" one. An attempt has been made to reproduce one of the one-second negatives by heliogravure process, in the accompanying illustration. The great prominence is shown, though with serious loss in sharpness, but the rich details of coronal structure are completely lost. It seems impossible to reproduce coronas by mechanical processes, with any approach to justice to the subject.

THE WM. M. PIERSON CAMERA,
In charge of Sr. D. Cuvás and Professor Casarrs;
AND THE FLOYD CAMERA,
In charge of Professor Gimeno and Sr. D. Terradas.

The former of these has a Dallmeyer quadruplet objective, aperture 6 inches and focal length 33 inches. The latter has a Clark objective, 5 inches aperture and 67 inches focus. Both cameras were mounted on a clock-driven polar axis, which also carried two spectrographs, to be described later.

Seven exposures were made with each camera, the exposures with the two instruments beginning and ending at the same instants to avoid jarring. They were as follows, on Seed plates No. 27:—

No. 1,	2 seconds	No. 5,	16 seconds
2,	8 "	6,	4 "
3,	32 "	7,	2 "
4,	64 "		

These negatives have recorded the longer coronal streamers out to a distance of about two solar diameters from the limb of the Sun. They likewise were not injured by the clouds, and they will be very valuable in a study of the middle and outer coronal forms. The attempted reproduction of one of the Floyd negatives shows only the general features of the corona, and fails completely to reproduce any of the exquisite detail of the original.

THE INTRAMERCURIAL-PLANET CAMERAS.

In charge of Mr. PERRINE, assisted by Messrs. GREVE, IBAÑEZ, HERNANDEZ, and HERREROS.

The search for an intramercurial planet was to be carried on with lenses exactly similar to those used at the Labrador and Egypt stations and to those used in Sumatra in 1901: 3 inches aperture and 11 feet 4 inches focus, constructed by ALVAN CLARK & SONS. The region to be photographed comprised an area 29° long, in the direction of the Sun's equator, by 9¼° wide. The Sun was in the center of this region. Four cameras were fastened together rigidly and mounted on a clock-driven polar axis so as to cover the entire region, using plates 18 × 22 inches in size. Two sets of exposures as long as possible furnished duplicate plates for the detection of defects.

The programme was carried through at the time of the eclipse as planned. The clouds interferred to such an extent, however, that it is not believed that the photographs will add anything to the results obtained at the Sumatra eclipse. The negatives have not yet been closely examined.

The intramercurial apparatus is shown, in the illustration of the camp, to the right of the 40-foot camera, though on a small scale. The corresponding apparatus of the Labrador expedition is shown, on a larger scale, in these *Publications* (No. 105, p. 180), and that of the Egyptian expedition in the present number (p. 37). The three mountings were designed by Mr. PERRINE and constructed under his immediate superintendence. They were very rigid and worked well.

OBJECTIVE-PRISM SPECTROGRAPH WITH STATIONARY PLATES.

In charge of Professor HARTMANN.

The purpose of this instrument was to secure a series of photographs of the changing spectrum of the Sun's edge at

and near the times of beginning and ending of totality, in accordance with the method first used successfully by Mr. SHACKLETON at the eclipse of 1896. The spectrum of the reversing layer, i. e. the "flash spectrum" near the beginning and end, was especially desired.

The optical parts of the instrument consisted of two objective-prisms of moderately dense flint glass, refracting angle 60°, refracting edges 2⅛ inches long, with faces 3¾ and 3⅞ inches long, respectively, placed immediately in front of a triple lens, aperture 2⅛ inches, focal length 60 inches, corrected for Hγ central. The plate-holder, holding seven Seed No. 27 plates, each 1¾ × 10 inches, was carried in a long slide. Brass racks fastened to the back of the plate-holder, and pinions supported by the slide and working in the racks, were the simple means of giving motion to the plate-holder. As soon as an exposure had been made on one narrow plate, one rotation of the pinions (by means of a small crank) brought the next narrow plate into position. The exposing shutter was a simple flap of zinc directly in front of the sensitive plate. The mounting of the instrument was of sugar-pine wood, and it was supported upon timbers set in stone and cement. The spectrograph received its light from the 15-inch plane-mirror of a cœlostat kindly loaned to the expedition by the Yerkes Observatory. The various parts of the instrument were adjusted to each other, and the instrument as a whole was adjusted to bring the Hγ region approximately to the center of the plate and the length of spectrum parallel to the edge of the plate several days before the eclipse. It was brought into final position a few minutes before totality.

In accordance with Mr. CAMPBELL'S instructions, it had been intended to make the first exposure several seconds before totality, to record the Fraunhofer spectrum, and to begin the second exposure at three seconds before totality, to record the flash spectrum. The coming of totality 17 seconds before it had been expected interfered with carrying out this programme, but fortunately Dr. HARTMANN, who was watching the progress of the eclipse with a small hand spectroscope, recognized its earlier arrival, and made his first exposure three seconds before totality, with estimated duration $0^s.4$. Development of the plate showed that the photosphere was still visible

on one section of the Sun's limb, but that the reversing layer was isolated from the photosphere on an adjoining section. The result is a magnificent photograph, showing the continuous and dark-line spectrum for one section and the bright-line spectrum (many hundreds of bright crescents) for the other section. The plate is in splendid focus from about λ 4800 to λ 3700. The Hβ bright line near one end of the plate is out of focus, unavoidably, just enough to make it clearly doubled.

The seven exposures made by Dr. HARTMANN were:—

No. 1, Exp. $0^s.4$, three seconds before totality.
2, " 0 .4, immediately after totality began.
3, " 60 .0, from $0^m\ 12^s$ to $1^m\ 12^s$.
4, " 120 .0, from 1 16 to 3 16
5, " 3 .0, after totality was over.
6, " 0 .4, " " " "
7, " 0 .4, " " " "

Plate No. 2 shows the high-level bright lines. Plate No. 5 is overexposed for the continuous spectrum, but shows the flash spectrum well on one side of the Fraunhofer spectrum.

A study of this very successful series of photographs, involving much labor, should supply extensive and accurate information as to the structure of the reversing layer.

OBJECTIVE-PRISM SPECTROGRAPH WITH MOVING PLATE.

In charge of Professor ARRHENIUS.

Photographs of the reversing-layer spectrum, taken in the usual manner with objective-prism instruments, such as that described in the preceding paragraphs, are integrated effects. Changes taking place during the exposure are not differentiated, and changes taking place between exposures are entirely lost. A continuous record of the changing spectrum is a great desideratum. A simple addition to the objective-prism spectrograph enables this to be obtained for a short length of solar limb. The usual reversing-layer spectrum consists of a series of crescents, each crescent an image of the uneclipsed portion of the Sun. A slit running centrally through the spectrum, placed all but in contact with the photographic plate, permits

a short central section of each crescent to fall upon the plate. If the plate is given a slow continuous motion by suitable mechanical means, a fresh part of the plate will be brought under the slit, and the changing spectrum will be recorded continuously. This method was devised and used by Mr. CAMPBELL in India in 1898 and in Georgia in 1900. At the latter eclipse an exposure beginning about 10 seconds before the end of totality, and continuing until 12 seconds after totality was over, recorded more than nine hundred bright lines and their succeeding dark lines.

The instrument used by Professor ARRHENIUS was equipped in the manner just described. The two objective prisms were of moderately dense flint glass, Jena No. 0.102, refracting angle 63° 27'.5, length of refracting edge 2 inches, lengths of faces 3.47 and 3.95 inches, respectively. The triple lens had aperture 2⅛ inches and focal length 60 inches. The slit in front of the plate was 0.05 inch wide and 9½ inches long. The plate-holder was moved by a hydraulic piston actuated by a weight, modeled after the piston of the Potsdam spectroheliograph, The controlling valve was regulated to a speed of about 0.06 inch per second.

It had been intended to secure a moving photograph extending from 12 seconds before to 12 seconds after the instant of totality, and a similar photograph from 12 seconds before to 12 seconds after the end of totality. The first of these was prevented by the arrival of totality 17 seconds earlier than was expected, but the second exposure, extending from $3^m\ 33^s$ to $3^m\ 57^s$ after totality began, was entirely successful. The changing spectrum is shown admirably through all the phases from high-level strong bright lines, through the bright-line stage of the reversing layer, and into the ordinary dark-line stage. There are six or eight hundred lines recorded in the region $\lambda\ 3800 - \lambda\ 5200$, with $H\gamma$ central on the plate.

During totality the slit in front of the plate was rotated to one side of the field of view, and the full prismatic image fell on the plate, from 1^m to 3^m after the beginning of totality. The coronal rings at $\lambda\ 4231$ and $\lambda\ 3987$ are strongly recorded. For this exposure the plate was fixed in position.

This spectrograph also reeeived its light from the Yerkes Observatory cœlostat mirror.

ULTRA-VIOLET SPECTROGRAPH, WITH MOVING PLATE.

In charge of Mr. CAMPBELL, assisted by Dr. KOBB.

In order to extend further into the violet the study of the reversing-layer spectrum with a continuously moving plate, a spectrograph was constructed whose optical parts should be efficient for ultra-violet light, as follows: Two objective prisms of Jena ultra-violet glass No. 3199, refracting angles 60°, refracting edges 60^{mm}, and lengths of faces 100^{mm} and 110^{mm}, respectively. A special lens of ultra-violet glasses, aperture 66^{mm} and focal length 2000^{mm}. A cœlostat mirror of Schroeder's metal No. 1, diameter 110^{mm} and thickness 15^{mm}, attached to the lower end of the Lick Observatory cœlostat's polar axis.

The foregoing parts were ordered from CARL ZEISS in October, 1904, delivery promised in February, 1905. As they did not reach Mt. Hamilton until the first week in June, after the necessarily unfinished wooden mounting was packed for shipment, the instrument was completed in Spain with time that could ill be spared for the purpose.

The plate-holder was moved by a weighted piston, as in the case of the preceding spectrograph operated by Professor ARRHENIUS.

This ultra-violet spectrograph is shown in position at the observing station in the accompanying illustration. The Lick Observatory cœlostat, seen in the same photograph, carries a 12-inch flat mirror by PETITDIDIER, as well as the Schroeder's-metal mirror.

The exposures planned for this spectrograph were identical with those for Professor ARRHENIUS's instrument. Those actually made, on account of the earlier arrival of totality, were identical with his for the exposure with fixed plate, from 1^m to 3^m, and for the exposure with moving plate, $3^m\ 33^s$ to $3^m\ 57^s$. The thin clouds interfered with the passing of ultra-violet light; and while the record extends to perhaps λ 3200, the spectrum is weak in intensity, only the stronger ultra-violet lines being shown. The dispersion of the ultra-violet glass is very low; the linear dispersion of λ 3200 and λ 5200 is but 150^{mm} for the two 60° prisms and focal length of camera 2000^{mm}.

The exposure with fixed plate recorded two strong coronal

rings, at λ 3388 and λ 3456, which have been noted by several observers since 1898.

Great care was taken in focusing the objective-prism spectrographs, by the following method:—

A parabolic silver-on-glass reflector, diameter 10 inches and focal length 10 feet 2 inches, by PETITDIDIER, was mounted in a horizontal tube of seasoned wood, and pointed to the mirror of the cœlostat in such a position that the rays from a bright star (parallel light) would cover the parabolic mirror and be brought to a focus on its axis. This focal point was determined very accurately by photography. A spectroscope slit was then mounted with its surface exactly in this focus. An iron electric spark from electrodes a few inches out from the slit was focused on the slit. The cone of rays passing through the slit completely covered the parabolic mirror. The spectrograph to be focused was mounted with its first prism just to one side of the slit so that the (parallel) rays from the mirror would cover the prism, and the ray of desired wave-length be brought to the center of the photographic plate. The usual methods of focusing the plate were then applicable. The entire process worked well and was exceedingly convenient.

OBJECTIVE GRATING SPECTROGRAPH.

In charge of Dr. KOBB.

This instrument, shown just beyond the ultra-violet spectrograph in the illustration, received its light from the Lick Observatory cœlostat. A plane Rowland grating, 14.438 lines to the inch, set for the third order, received the light, and returned it through a (visual) camera-lens 2⅛-inch aperture, 20½-inch focal length, to a Cramer's isochromatic plate. The region of the green coronal ring at λ 5303 was central in the field. A yellow-green color-screen was fastened immediately in front of the plate to cut out the overlapping spectrum. The purpose of the exposure, extending throughout the total phase, was to record the green ring, in order to determine whether the layer giving rise to its light was uniformly distributed around the Sun, or not. Owing partly to the clouds and partly to the light-consuming properties of the optical train, the image of the ring secured is exceedingly faint, and not much can be said from it as to the law of distribution, but there is little doubt that the ring is of quite irregular intensity.

The distribution at other recent eclipses, at times of sun-spot minimum, was exceedingly irregular.

THREE-PRISM SLIT SPECTROGRAPH.

In charge of Mr. PALMER.

The purpose of this instrument was to determine the wave-length of the green coronal line near λ 5303. It was mounted on a clock-driven polar axis, pointed directly toward the Sun, and received its light from an image-lens (visual) of aperture 1½ inches and focus 10½ inches. The slit-jaws were curved to a radius of 3.30 inches to make the recorded spectrum lines straight for ease and accuracy in measurement. It was placed east and west across the Sun's image. The collimator-lens (visual) was of 2⅛-inch aperture and 20½ inches focus. The three extra dense flint prisms had refracting angles of 60°, refracting edge 2⅛, 2¼, and 2¼ inches, respectively, and length of faces 3⅝ inches. The deviation for λ 5303 was 169° 36′. The triple camera-lens (visual) had aperture 2⅛ inches and focal length 20½ inches. A movable diaphragm in front of the slit had six holes so arranged that the coronal spectrum from the east limb of the Sun would have a sky spectrum on either side of it for comparison, and similarly for the coronal spectrum on the west limb.

The images of the green line on the plate, exposed throughout totality, are likewise very faint, and capable only of approximate measurement.

SINGLE-PRISM SPECTROGRAPH.

In charge of Mr. PALMER.

This instrument was mounted beside the one just described, and received its light in the same way. Its purpose was to record the general spectrum of the corona.

The image of the Sun on the slit was formed by a lens of 1⅝-inch aperture and 13 inches focus. The collimator-lens was of 2 inches aperture and 32 inches focus, corrected for Hγ. The prism was of Jena glass No. 0.102, angle 63° 27′, refracting edge 2¼ inches, length of face 4.55 inches. The camera-lens was of aperture 2 1/16 inches and focal length 12 inches, corrected for Hδ. The region between Hγ and Hδ occupied the center of the field.

The exposure continued throughout the total phase. The

spectrum is strongly recorded. That of the inner corona shows no Fraunhofer dark lines, whereas they are strong in the spectrum of the outer corona. They are also shown, less strongly, on the area occupied by the Moon. It is thus clear that our own atmosphere, or perhaps the clouds, diffused the light to a considerable extent, and the results are more difficult to interpret on that account.

THE POLARIGRAPHS AND PHOTOMETER.

In charge of Professor McKINNEY, assisted by Professor ROCASOLANO, Mrs. CAMPBELL, Mrs. PERRINE, and Srs. BARBAJOSSA and BLASCO.

The observations of the polarized light in the corona of 1901, with a double-image prism, were very successful. Owing to the dispersion of the prism, however, and to the small scale of the images, it was not possible to measure the intensities with the necessary accuracy for determining reliable values of the polarization. In addition to the double-image camera, which was again used, new apparatus was designed by Mr. PERRINE for polarization observations at the recent eclipse. Three cameras composed this apparatus. Two of these had plane-glass reflectors in front of the objectives to serve as analyzers, while the third camera was used to secure an unpolarized image of the corona as a standard of comparison. The aperture of this direct camera was reduced so that the image obtained with it would be of approximately the same intensity as an (*unpolarized*) image with the other two cameras, after reflection from the plane-glass surfaces. The plane-glass analyzers were set at the angle of maximum polarization. Their principal axes were adjusted, one parallel to a north-and-south line and the other to an east-and-west line, through the corona. In this way polarization was observed along four different radii of the corona. The three cameras have focal lengths of 50 inches, which give images of the corona 2½ times the diameter of that obtained with the double-image camera. The four polarigraphs were mounted on one polar axis.

The performance of these cameras was highly satisfactory. They yielded sharp images, which are of sufficient size to permit quite accurate determinations of intensity to be made.

Four sets of negatives were secured with these instruments, with exposures of 1, 4, 20, and 115 seconds. Of these the 1-second and 115-second series are unsuitable for the best

results, owing partly to the diffused light from the clouds, which affected the sky background differently in the different cameras. This effect was enhanced in the case of the first series by some of the slides having been drawn unnecessarily early.

The 4-second and 20-second series are well suited for accurate determinations of the amount of polarized light in the inner-middle and middle corona. No numerical results have yet been obtained, as special apparatus is necessary for the photometric measurement of these negatives. The polarization is well marked, however.

An effort was made to compare the brightness of the corona with that of the full Moon by impressing a series of standard squares near the ends of two dry plates, with the Moon as the source of light, and then exposing the central portion of each plate to the light of the corona in a suitable camera, *without any lens.* This camera was arranged to admit the light from a circular area of sky 4° in diameter, the corona being in the center.

Two exposures were made during the eclipse of 14 seconds and 50 seconds, respectively.

It will be necessary to determine the effect of the clouds and of the sky background before any definite result can be arrived at.

The negatives were developed at the station on the four days and nights following the eclipse, simultaneously with the dissecting and packing of the instruments. It was a satisfaction to find so large a proportion of the photographs of such excellent quality, notwithstanding the clouds. A cloud of any kind over the Sun at an eclipse looks pretty thick to those who have been preparing for fourteen months to observe the event!

The photographs and instruments, carefully packed for the long journey home, were shipped from Alhama on the evening of September 3d to Barcelona and thence by steamer sailing directly to New York. Farewell visits to the officials of Alhama, the settling of accounts, and the closing of a voluminous correspondence terminated our eclipse duties abroad.

An eclipse expedition to a distant country is a complex matter. A large number of delicate scientific instruments are to be made ready, and tested at home, with reference to their fitness for securing observations demanded in the solution of definite solar problems. Their transport by wagon, rail, and ship to and from the distant station, to insure that they shall arrive safely and on time, must be the subject of much thought and anxiety. The construction and operation of the station will require hundreds of tools and items of supply, and to have them one must take them with him. There are the observers to arrange for and train to the programme. All the instruments and all the observers must do their parts, not at some time when it is convenient, but on a given day, minute, and second. The astronomer charged with the duty of bringing these things to pass is an optimist, for at all points where he needs assistance there are men ready to help him.

The Crocker expeditions are deeply indebted to many institutions and people.

During the months preceding the departure from Mt. Hamilton the Director was especially indebted to His Excellency WILLIAM MCGREGOR, Governor of Newfoundland; to Hon. BENJAMIN H. RIDGELY, U. S. Consul-General at Barcelona; and to Captain H. G. LYONS, R. E., Director-General of the Egyptian Survey; all of whom frequently supplied information of great value.

Harvard College Observatory loaned four intramercurial lenses for use in Labrador.

Princeton University loaned a lens, 5 inches aperture, 40-foot focus, for use in Labrador.

The University of Illinois loaned a sextant and a thermograph for use in Labrador.

The Yerkes Observatory loaned a 16-inch cœlostat complete for use in Spain.

The Solar Observatory of the Carnegie Institution loaned a thermograph for use in Spain.

The U. S. Naval Observatory loaned a 5-inch lens, focal length 40 feet, for use in Egypt.

The Santa Clara College loaned a sextant for use in Egypt.

The following gentlemen arranged for the satisfactory transport of observers and freight from San Jose to New York and return:—

Mr. JAMES HORSBURGH, Jr., Assistant General Passenger Agent; Mr. G. W. LUCE, General Freight Agent; and Mr. PAUL SHOUP, District Freight and Passenger Agent; all of the Southern Pacific Company.

Mr. L. J. SPENCE, General Eastern Freight Agent, Southern Pacific Company, and many of his staff assisted with the freight in and through New York. Mr. PENNELL, Dock Superintendent of the White Star Line extended favors in the transport of the Spanish and Egyptian freight.

Mr. JAMES J. ROCHE, U. S. Consul at Genoa, had all arrangements made for a quick transfer of instruments and baggage to the steamer for Barcelona, if the "Romanic" had arrived before the hour of sailing.

Sig. CARLO FIGARI, of Genoa, obtained information and accommodations for the party and equipment on the steamer "Jativa" from Genoa to Barcelona, and otherwise assisted in the transfer.

Special mention must be made of the help afforded by Mr. BENJAMIN H. RIDGELY, U. S. Consul-General at Barcelona, in supplying a great deal of accurate information in the months preceding our departure from Mt. Hamilton, in expediting the importation and exportation of the instruments, and in arranging for the purchase of lumber and many other supplies. His experience was wide, his judgment was excellent, and his assistance was always efficient. We depended upon him in many ways.

His Excellency WM. MILLER COLLIER, the American Ambassador at Madrid, and Mr. MADDEN SOMMERS, American Vice-Consul at Madrid, responded efficiently to requests for information or advice.

Mr. E. J. MOLERA, of San Francisco, formerly of Spain, long a valued friend of the Observatory, and a past President of the Astronomical Society of the Pacific, held the needs of this expedition in mind from more than a year before preparations began until it was ready to leave San Francisco. He did us many valuable services in this country, still other services in

Spain, and his thoughts were with us throughout our stay in his native land.

Mr. MOLERA's friend, Professor CASARES, of the Central University, Madrid, whom we had the pleasure of seeing on Mt. Hamilton two years ago, and the latter's friend, Sr. D. ARTURO CUYÁS, who had lived in New York for forty years, together met Mr. CAMPBELL in Madrid before the station was selected and inaugurated several plans that proved helpful. At their request the Minister of the Interior telegraphed to the Governor of the Province of Zaragoza that we were coming into his territory, and asked that he issue suitable instructions to the Alcalde of Alhama to supply our wants as far as possible. In the same way instructions were issued to the Guardia Civil to have an eye to our safety wherever our work might carry us. Sr. CUYÁS and Professor CASARES kept us in mind during our entire stay in Spain, and came to help in the observations. The expedition is deeply indebted to these gentlemen.

Sr. D. V. LUIS, Director-General of the Madrid, Zaragoza, and Alicante Railway, arranged most kindly to expedite the shipments of the apparatus from Barcelona to Alhama and return, by ordering that they should come by "mixed train," instead of by slow freight, without additional expense.

To Director IÑIGUEZ, of the Madrid Observatory, we were indebted for time signals and other scientific favors.

Sr. D. LISARDO HERRANZ, Alcalde of Alhama, and Sr. D. ENRIQUE IBAÑEZ, the extremely capable Secretary of the Municipality, were deeply interested in the expedition, its work, and its requirements, and were constant in their efforts to make it a complete success. Through their kind offices were made all the arrangements to meet the local material wants of the expedition. They never permitted many days to pass without inquiring as to the progress of the preparations and as to whether there was any help they could give.

The expedition received frequent favors from the telegraphic offices of the Government,—Sr. D. FELIPE HERREROS, Agent at Alhama, to whom our thanks are due.

Acknowledgments are due to the members of the Guardia Civil, Srs. BARBAJOSSA and BLASCO, who went beyond the letter of their instructions in their zeal to avoid any misfortunes to the instruments from mischief-makers or otherwise.

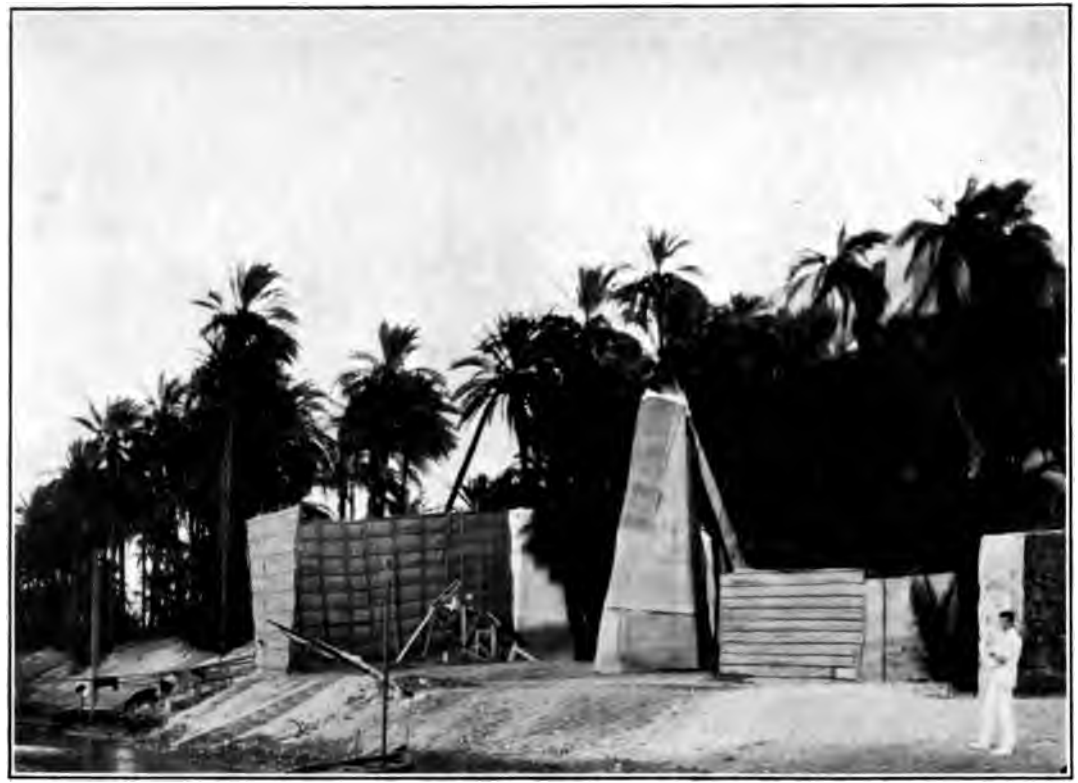
The laborers recommended to us were splendid. They were willing, prompt, strong, and intelligent. To the interested help of JOSÉ, VICENTE, JUAN, and SEBASTIAN the expedition owed much.

To the gentlemen who journeyed from northern Europe, from the cities and universities of Spain, and to those citizens of Alhama who gave of their time in order to assist in the observations, we desire to offer special thanks.

Relieved of responsibilities at the close of eclipse duties, we were psychologically ready to enter upon vacation journeys. These were entirely apart from the eclipse expedition, and had for their principal purpose the paying of visits to many of the astronomers and observatories of Europe. In common with ourselves, several Dutch, English, French, German, and Italian astronomers who had eclipse stations in various parts of Spain journeyed to Madrid after the event was past, where all attended a splendid banquet given for them by the Municipality of Madrid, presided over by the Alcalde, Sr. D. EDUARDO RIGUERA. Many attended a bull-fight as guests of the city.

At the end of a few days in Madrid, Mr. and Mrs. PERRINE traveled by way of Granada and Gibraltar to Naples for a trip through Italy, Switzerland, Germany, Holland, and England. Mr. and Mrs. CAMPBELL went northward by way of El Escorial and Burgos to Switzerland and down the Rhine to attend the Solar Conference in Oxford; thence to central Germany and Pulkowa, returning again to England to sail from Liverpool on November 1st in company with Mr. and Mrs. PERRINE.

The effects of the three expeditions reached Mt. Hamilton late in November, all in good order.



LICK OBSERVATORY-CROCKER ECLIPSE STATION AT ELEPHANTINE ISLAND, ASWAN, EGYPT.

THE LICK OBSERVATORY-CROCKER ECLIPSE EXPEDITION TO EGYPT.

By W. J. Hussey.

To be charged with the conduct of an eclipse expedition is a duty always prized by the astronomer, not only for the opportunity it gives to see and study a rare and beautiful phenomenon, but also for the advantages which come from voyages to far parts of the Earth, the experience of new and varied conditions, and the meeting with others who likewise journey to an unique errand. It therefore afforded me great pleasure to be intrusted with the expedition sent out by the Lick Observatory to Egypt, a country full of interest in and for itself, and with a background of history the most remarkable known to the world.

Accompanied by Mrs. Hussey, I left California early in June for a short holiday season in Switzerland and Italy. The equipment for the Egyptian expedition was brought later with that of the expedition to Spain, by Professor Perrine, from New York to Naples, where I met him on the arrival of the steamship "Romanic," on the 19th of July. The Egyptian freight was transferred by lighter to the custom-house, where it remained for a week in bond, until the next sailing for Alexandria.

A distinctive endeavor of the Lick Observatory at the recent eclipse was, in addition to an extensive programme of photographic, spectrographic, and polarigraphic work to be carried on at the central station in Spain, to secure comparative data respecting coronal changes and possible intramercurial planets by the establishment of terminal stations in Egypt and the Labrador. This fact gave triple interest to our undertaking, keeping constantly in mind the thought of our colleagues at the other stations, and especially the contrast between our conditions on the tropical borders with those of the Labrador under the Arctic Circle. There were no icebergs to skirt our path as our fruit-laden ship steamed through the Strait of Messina and down the blue Mediterranean, four days to the south from Naples. No snow lay in gullies, nor heavy

mists hid the headlands when we again sighted land. The yellow shores of Africa stretched long and low in the face of a cloudless dawn. The yellow bluffs at the right were penciled with thin palms, erect, campanulate, like the wands that Cleopatra's women held before her when, in these very waters, she came down to meet the Roman galleys. But the lantern of the Pharos on the left, far less kin to the ancient world, brought us sharply back to the present day and the modern city of Alexandria before us, Oriental only in its thronging street-life and in all the costumes and colors of the East.

The floating dock was adjusted by brown men in baggy trousers and various headgears, whose contrasting features betrayed a dozen different tribes or nationalities. Scarcely was the ship moored when there appeared on the deck two Englishmen, who came to us as directly as old acquaintances, Captain H. G. LYONS, R. E., Director-General of the Survey Department, Egypt, and one of his Inspectors, Mr. B. F. E. KEELING, now the Acting Director of the Helwan Observatory. Thereupon began the pleasantest experience of being "personally conducted" we have known, an experience lasting to the day of our leaving this delightful land. The numberless courtesies afforded us by Captain LYONS and his staff were, he assured us, "by order of the Egyptian Government." Certainly we wish that the powers responsible might know how thoroughly all the visiting expeditions appreciated the favors of which they were the recipients during their stay in the country of the Nile.

In Cairo we passed some days, during which Professor TURNER arrived from Oxford, and later Mr. BELLAMY with the British expedition freight. Our colleague-to-be, Professor ROBERT H. WEST, of the Syrian Protestant College at Beirut, here joined us, and we perfected our plans and arrangements for the station work at Aswan. The American expedition was favored with some delightful courtesies, notably from Mr. FREDERICK GRINNELL MORGAN, Consul-Gerant of the United States, and from the Bureau of Antiquities, the Railway Administration, and various members of the Survey Department staff. We were taken by Government launch to the great Delta and Aswan Barrages, and in seeing the Pyramids

and the most interesting points in and about Cairo, at Luxor and Aswan, were never left to the mercy of the dragoman. Professor WEST, as well as Captain LYONS and his engineers, spoke Arabic fluently, with the result that our impression of the Egyptians throughout our stay was of quite a different nature from that of the ordinary traveler.

Three expeditions, Russian, British, and American, were expected to arrive in Cairo during the first week of August, and Captain LYONS had arranged that all should go together by the through train of the evening of Monday, the 7th, arriving at Aswan the following afternoon. The Russians, however, were delayed, and leaving Mr. DICKINSON to meet and escort them later, Captain LYONS, with Mr. KEELING, accompanied the others as planned. The train which awaited us was well equipped, and the night passed in comfort, with only the regret that in our rapid travel we were missing the sight of the vastly interesting country of the Lower Nile Basin. In the morning we passed Sohag, reminiscent of the eclipse of 1882, when the first photographic comet was found on the plates obtained by the British expedition.

Our journey was hot and dusty, of course, for this was Egypt and the month was August. But we had suffered worse in New York from humid heat, and on the Western plains from alkaline dust. However, our impressions here were not what they might have been but for Captain LYONS's thoughtfulness. He knew Upper Egypt and the "Soudan thirst." Therefore, we were especially supplied with fruit and drink for the last stages of the desert from Luxor. Here the railway changes from standard to narrow-gauge. The dining-car and the comfortable sleeper are left behind, and we have instead a queer-looking train of double-sided and double-roofed cars, those of the first class having two compartments, equipped with easy leather-bottomed chairs, movable, but ranged along the outer walls, facing each other. Half the car was assigned to our party, and, with our ice-boxes, provision-baskets, and pith helmets, we filled it, just.

All the afternoon we were thinking of the work ahead of us in the heat, the full force of which we were only now beginning to realize. The desert ran to the river's edge, shimmering in the sun, or melting back toward the distant cliffs into a

blue mirage of false lakes and lagoons. Interest grew as we approached Kom Ombo, where the edge of the eclipse shadow would pass. It was the height of the afternoon, and we went out to dicker with the Arabs for white grapes. A "bolis" (policeman) stood patron to each bargain, signaling the passenger what was fair and compelling the Arab to give full weight. We returned to the relief of the blue-windowed car, putting our grapes to cool in the ice-water.

Later came Khatara, where the Russian expedition expected to stop, as it was on the central line of the eclipse. We looked at the little sun-dried town and predicted that the Russians would follow us to Aswan, wondering meanwhile what we should find there. What we did find was a shining city,—dried mud and Arab shacks in the rear, to be sure, but two- and three-storied in front and white-painted by Kitchener's decree, with such a water-front as no other Upper Egyptian town can boast, though little they like him for it.

Directly in front of Aswan lies Elephantine, the long island at the foot of the First Cataract, with the Savoy Hotel conspicuous on its north point. Arrangements had been made by Captain LYONS for the accommodation of the several expeditions at this hotel, which is usually closed at this season. Thither we were at once transferred by sail-boats which were waiting just below the station. Here indeed was no Khatara, but a European hostelry, in pleasant gardens, past which the river swept on either side in strong current, for the time of flood was approaching.

Our first desire was to prospect for sites for our stations. In the sunset Captain LYONS, Professor TURNER, Professor WEST, and the writer took a brisk walk through the native villages and the dhurra-fields to the upper end of the island, where the remains of ancient Elephantine rise in mounds of stratified débris, formed as one century built upon the crumbling ruins of the preceding. Here there are Roman fragments, too, of TRAJAN'S time. Perchance besides these very columns JUVENAL may have watched that Sun go down, reflecting upon the clever irony of his honorable exile. But no less to him than to us the Pharaohs were dead and Yebu forgotten, and the princes of Elephantine slumbered in their rock-hewn tombs.

As a result of our tour of inspection we came to the con-

clusion that the best sites for the eclipse stations were near the north end of the island in the hotel grounds. Permission was readily granted us to establish our stations within the gardens, and my choice fell at once upon a sandy strip of Nile bank adjacent to the west wing of the hotel. This site was shaded during much of the forenoon by a thicket of young palms, overtopped by old trees fifty or more feet in height, but afforded an unobstructed view toward the west, the low hills beyond the river rising only four degrees above the horizon. Moreover, the broad stretch of water between this place and the mainland in the direction of prevailing wind added greatly to our comfort by reducing the amount of wind-blown sand, and doubtless also somewhat alleviated the bad effect of radiation from the contiguous desert.

In the midst of the palm thicket, adjacent to our station, was a thick-walled mud house, empty in summer, but used in winter for the storage of meat. At the outset the hotel management placed this at our disposal for a workshop. In this room and in the shade of the trees we unpacked and assembled the instruments in comparative comfort, though the maximum temperature day after day during the first weeks of our stay ranged from 108° to 110°, and even touched 113°. The coolest rooms of the hotel rarely fell below 90°, and even at bedtime they were often above 100°. The air was so dry that this heat caused no lassitude. The sensation of having everything about warmer than one's self was novel and an ever-present argument against restlessness. When one had cooled the bed to his own temperature it was well to lie still in that spot. Out of doors late at night the thermometer might fall to the eighties, and to sleep on the roof or balconies has come to be the well-nigh universal custom.

The Egyptian sky is impressive as a spectacle, but, so far as my observations go, the seeing at this time of year is not of good quality. As might be expected the great heated areas, with rapid radiation, cause trembling images, which in a powerful instrument would seriously interfere with effective work. At no time, with the photographic tests, was I able to secure clear definition. Through the kindness of Captain LYONS, Mr. WADE sent to Aswan the eight-inch objective of the Helwan Observatory, in the hope that I might mount it

for visual tests. Other work, however, took my time to its exclusion.

Labor was cheap and abundant at Aswan. While our colleagues in the Labrador were finding it impossible, on account of the salmon run, to get a man at any price, we could have had any number at twenty-five cents a day. The custom of the country is to work through native overseers, and to our surprise we found that Captain LYONS had provided even for this need, and had brought four of those in the employ of the Survey Department on the same train with us from Cairo. One of these, MURSI, was assigned to the Lick Observatory camp, and the others to the English and Russian parties, for the Russians, as predicted, had promptly joined us at Elephantine. Through Mr. KEELING and MURSI, the selection of day and night watchmen, of laborers, and of contractors for building the necessary piers and an effective wind-screen were soon effected. The routine of the establishment of the eclipse apparatus progressed steadily, but without haste.

During the week preceding the eclipse, Mr. JOY, a graduate of Oberlin, and Mr. NELSON, an alumnus of the University of Chicago, joined the Lick Observatory expedition from Beirut. Captain LYONS returned to assist Professor TURNER with the Oxford expedition, but kept an active interest in us all, still seeing something to offer for our advantage or assistance. He secured us the added services of Messrs. TRIMAN, DRAY, and CURRY, of the Survey Department, in Cairo, and of Messrs. SWIFT and WILD, of the Ministry of Public Instruction.

During these last days we were all keenly interested in the arrival of Mr. REYNOLDS from Birmingham with a reflector of twenty-eight inches aperture and one hundred twenty feet focal length, and in the heroic effort to install it in time for the eclipse.

The 30th of August was absolutely clear, with a light wind, and a temperature of 108° in the afternoon. It was one of the most favorable days we had at Aswan, except that the sky was white with fine dust driven high in the air by a gale from the desert the day before. During the morning the equipment was critically examined. The plate-holders especially were inspected for any light leaks, additional thicknesses of black cloth were obtained to be placed before the tent door, and for

wrapping about the plate-holders when they were carried from the dark-room to the instruments. The entire spectroscope except the objective and a place to draw the slide was thickly wrapped in layer after layer of black cloth.

As the hour approached the plates were backed with a non-halation covering, placed in their holders, and wrapped thickly in black cloth. During the last moments of the partial phase these were carried from the dark-room to their respective instruments. The operators were in their places, alert for the signals of time, and ready each for his especial duty.

The exposures with the forty-foot camera were made by the writer, with Mr. DRAY, of Cairo, assisting. Professor WEST was given general charge of the programme in the open, with Mr. TRIMEN as time-counter, and Mr. JOY at the spectroscope. At the intramercurial apparatus were Messrs. SWIFT, WILD, CURRY, NELSON, and Mr. BRUCE J. GIFFEN, of the American Mission at Luxor. Mr. GODFREY, of Zagazig, who happened to be present and offered his services, was asked to watch for shadow-bands against the tent of the forty-foot telescope. Mrs. HUSSEY, with Mr. ARTHUR KNOWLES, of Cairo, and Mr. GEORGE CALLENDAR BRACKETT, of Brooklyn, New York, also observed the shadow-bands against the tower of the Savoy roof.

The programme at the instruments was carried through with automatic precision. Each operator performed his part to the second, and the work was so planned that every one had at some time during totality a period free for viewing the eclipse. The Sun was nearly in the west, at an altitude of twenty-four degrees, for the afternoon was well advanced, the total phase beginning at $4^h\ 33^m\ 34^s$ mean local time. The computed duration of totality was two minutes thirty-one seconds.

The corona was of the usual sun-spot maximum type. The south preceding streamer, however, was noticeably long, slender, and recurving. By reason of the light sky, the corona was less brilliant to the eye than it had been to those who had seen other eclipses in localities with rain-washed atmosphere. But in respect to the prominences, it would seem that nothing could have been more impressive.

Immediately after the total phase had passed, the plates

were taken to the dark-room and stored to await development. There was an hour of frank congratulation over the tea and shandygaff, but there was no disguising the weariness of the observers after the long day and the event to which all the company had been intensely keyed.

The hotel terrace in the evening, with its notable visitors from down the river, seemed quite gay to us who had so long possessed it exclusively, and the banquet given on the lawn below in the gardens by Mr. MITCHELL-INNES, Under-Secretary of State for Finance, to the eclipse expeditions, Captain LYONS, the Mudir of Aswan, and other guests, brought to a delightful ending our weeks of pleasant association.

Sunrise saw the departure of Mr. MITCHELL-INNES's steamer, with Captain LYONS aboard. The guests of the hotel went, most of them, by the morning train to Luxor. Many of the assistants remained to help dismount the instruments and straighten up the camps, and by evening of the 31st little remained to mark their sites. M. OCULVITCH and M. BAIKOFF packed their plates for development at St. Petersburg. Dr. MEYER, of Berlin, boxed his portable Zeiss altazimuth and departed for Italy. Mr. REYNOLDS and Mr. KEELING were off for Helwan, to install the thirty-inch reflector that Mr. REYNOLDS has presented to the Egyptian Government, and from which we hope to hear notable things in the near future. Professor TURNER and Mr. BELLAMY took the train to Cairo, carrying their plates to the spacious dark-rooms of the Survey Department for development. Professor WEST had sailed from Port Said for his mountain home in Syria, leaving us conscious of the loss of his resourcefulness, his congenial companionship, and his invaluable aid in all ways during our association at Aswan. In addition to his technical skill, his mastery of Arabic and his insight into Oriental character were no small factors in establishing the cordial relations with our native helpers, which continued to the end of our stay at Elephantine.

The company at the Savoy had now dwindled to ourselves, Mr. DICKINSON, and M. DUBINSKY, of Pawlowsk, who for nearly a fortnight longer continued his magnetic observations in the tomb of one of the ancient princes of Elephantine. He had here ideal rooms for his work, cut one beyond the other into the side of the hill of the Dome of the Winds, away from all

THE FORTY-FOOT CAMERA AND INTRAMERCURIAL APPARATUS AT ELEPHANTINE ISLAND.

disturbing surface conditions, the range of temperature day after day amounting to less than a degree Fahrenheit.

The last ten days of our stay at Aswan proved the most trying that we had, for the winds dropped and the humidity rose above fifty. Operations in the dark-room were necessarily restricted to night and early morning, and the behavior of the chemicals in the heat and the uninterpreted action of other agencies added perplexities to the work of development. Our dark-rooms were improvised without sinks or running water. The hotel gave us the unlimited use of its filters, and the Survey Department sent up generous supplies of distilled water from Cairo, while the willing labor of our ABBAS and MOHAMMED furnished the Oriental equivalent of Yankee conveniences. Ice was an essential, of course, brought by train from Cairo daily.

Nineteen photographs were obtained, having exposures varying from half a second for the inner corona, to sixty-four seconds for the fainter outlying streamers. With the intra-mercurial apparatus the time of totality was divided as nearly as might be to obtain duplicate plates along the ecliptic in the vicinity of the Sun. The exposure with the spectrograph lasted throughout totality, except for a second or two at the beginning and end.

No detailed study of photographs is made at an eclipse camp. This requires the resources of measuring-engines, microscopes, comparison-plates, and other records. At the observing station the one object is to bring out all the detail the plates will yield and fix them against the chance of accident from light or chemical change. They are then packed in their original boxes, separated at their edges by strips of paper. These are then sealed in tin, and put in a strong wooden box, excelsior lined. This is then packed in one stronger still, and labeled, in this case in three languages, English, French, and Arabic, for shipment to Mt. Hamilton.

Eclipse successes and failures have always a stimulating effect. By the following of clues in the earnest endeavor to learn more of the many things that formerly could be studied only during the brief moments of totality the effective means of research have been greatly extended and have given us what may be called indirect eclipse results quantitatively more

numerous perhaps than those which have been obtained directly. Holding in mind the great practical importance of a more complete understanding of the Sun and the high probability of light being thrown upon its problems by observations that can at present be made only during the brief and long-separated total eclipses, it is apparent that every opportunity should be embraced to make the most of these occasions. It is to the credit of the Lick Observatory that it has played a conspicuous part in the observation of eclipses of the Sun, and not too much can be said in commendation of the systematic giving by which Mr. WILLIAM H. CROCKER, and, before him, the late Colonel CHARLES F. CROCKER, have made possible the continuous study and investigation of these phenomena by that institution.

DETROIT OBSERVATORY, UNIVERSITY OF MICHIGAN,
ANN ARBOR, January 22, 1906.

NOTE ON ANOMALOUS REFRACTION.

BY FRANK SCHLESINGER AND G. B. BLAIR.

Under normal conditions atmospheric strata of uniform density lie parallel to the Earth's surface. In this case the expression for refraction takes the well-known form $k \tan z$, in which z is the true zenith-distance of the object and k is a quantity that varies slowly with the zenith-distance, the temperature, and the height of the barometer. For present purposes, however, we may regard k as a constant and equal to $57''$.

Let us now consider the effect upon the refraction of a small inclination in the strata of uniform density. Imagine a normal to be drawn to these strata, and let ζ and α be respectively the zenith-distance and azimuth of the point at which this normal pierces the celestial sphere. This point is evidently the origin from which zenith-distances should be reckoned for the computation of the refraction under the assumed conditions. Consequently for z in the above formula

we should substitute (with a sufficient degree of approximation) $z - \zeta \cos (a - A)$, A being the azimuth of the object.

Hence the correction arising from anomalous refraction is

$$k \tan [z - \zeta \cos (a - A)] - k \tan z$$

or very nearly $k \cdot \zeta \cos (a - A) \sec^2 z \quad . \quad . \quad . \quad . \quad . \quad (1)$

For objects in the meridian this becomes

$$\pm k \zeta \cos a \sec^2 z \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The positive or negative sign is to be used according as the object is south or north of the zenith.

The following table gives the values for various zenith-distances of the coefficient of $\zeta \cos a$, the latter being expressed in minutes of arc:—

TABLE I.

z	Anomalous Refraction.
0°	0″.017 $\zeta \cos a$
10	0 .017 "
20	0 .019 "
30	0 .022 "
40	0 .028 "
50	0. 040 "
60	0 .067 "
70	0 .142 "

This table shows that the effect of anomalous refraction is nearly the same for all objects that culminate within 30° of the zenith, but that it increases rapidly when the zenith-distance surpasses 50°.

It will be instructive to apply the above formula to actual observations. So far as we know, the only ones suitable for the purpose are those which have been made at the six international latitude stations. The programme for observing at these stations includes, in each night's work, twelve pairs at small zenith-distances (never more than 23°), and four pairs at large zenith-distances[1] (about 60°). An ordinary programme—that is, one which contains pairs at small zenith-distances only—cannot be used for our purpose, since, as we have seen from Table I, the effect would be nearly the

[1] For brevity we shall refer to these as refraction pairs and to those near the zenith as zenith pairs.

same for all the pairs, and it would be impracticable to distinguish a refraction effect from any other disturbing phenomenon. Furthermore, it would be equally futile to attempt to deduce the value of $\zeta \cos a$ from absolute measures of declinations, since these do not possess the requisite accuracy.

The results of the first two years of the international work have been published by Dr. ALBRECHT in volume I of the "Resultate des Internationalen Breitendienstes." On the data given in this memoir Table II is based.

Column 1 gives the name of the station and column 2 the number (n) of nights during 1900 and 1901 on which all four of the refraction pairs, and at least ten of the twelve zenith pairs, were observed. No use is made of the other nights in the present paper, which, even with these restrictions, covers more than fourteen thousand separate determinations of the latitude. Column 3 contains the sums of the squares of the "zenith divergences" obtained thus: ALBRECHT'S Plate XI shows with red lines the definitive latitudes at the six stations; and on pages 130 to 139 are given the results for each night from the zenith pairs. The difference between these two quantities was taken for each night, and the sum of their squares for the whole two years is entered in column 3.

TABLE II.

1	2	3	4	5	6
	n	Zenith.	Refract.	Zenith minus Refract.	$\frac{\epsilon^2}{4} + \rho^2$
Mizusawa	77	0.2797	1.7880	1.6148	0.00073
Tschardjui	131	1.0221	3.4920	4.2131	0.00029
Carloforte	258	0.7848	3.6875	3.7293	0.00036
Gaithersburg ...	169	0.6422	2.6526	2.4720	0.00061
Cincinnati	131	0.6407	3.4664	3.0565	0.00100
Ukiah	165	0.3737	3.8113	4.1683	0.00001
Means	155				0.00050

Let ϵ be the mean error of the definitive latitude shown in ALBRECHT'S Plate XI.

ϵ_z, the mean error of the mean of the ten to twelve zenith pairs observed each night.

ρ, the mean effect of anomalous refraction at the zenith.

Then the numbers in column 3 may be represented by the expression

$$\Sigma\,(\epsilon^2 + \epsilon_z^2 + \rho^2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Column 4 contains quantities similar to those in column 3, except that the refraction pairs (pages 143 to 151) have been used instead of those near the zenith. Representing by ϵ_r the mean error of the mean of the four refraction pairs, and remembering that at 60° zenith-distance the effect of anomalous refraction is four times that at the zenith, the numbers in column 4 are the equivalents of

$$\Sigma\,(\epsilon^2 + \epsilon_r^2 + 16\rho^2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Column 5 gives the values of

$$\Sigma\,(\epsilon_z^2 + \epsilon_r^2 + 9\rho^2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

obtained by taking the differences between the refraction pairs for the same night, squaring and adding.

By adding corresponding items in columns 3 and 4, subtracting those in column 5, and dividing by $8n$, we evidently obtain

$$\frac{\epsilon^2}{4} + \rho^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

the values of which are given in column 6.

The data in Table II do not permit us to separate these two errors, but from other considerations[1] it is known that ϵ is about $\pm$ 0″.02. Whether we assume this value of ϵ or a smaller one, we should get practically the same values of ρ, as is shown by the following:—

TABLE III.

Values of ρ. assuming:	$\epsilon = \pm$ 0″.02	$\epsilon =$ 0″.00
Mizusawa	± 0″.025	± 0″.027
Tschardjui	.014	.017
Carloforte	.016	.019
Gaithersburg	.023	.025
Cincinnati	.030	.031
Ukiah	.000	.003
Means	± 0″.018	± 0″.020

Adopting the former as definitive, and substituting in expression (3) above, we get these values for the mean

[1] See the residuals on pages 163 to 166 of ALBRECHT'S memoir.

errors of the latitude as determined from one night's observations:—

TABLE IV.

	Values of ϵ_z.
Mizusawa	± 0″.051
Tschardjui	.085
Carloforte	.049
Gaithersburg	.054
Cincinnati	.060
Ukiah	.044
Mean	± 0″.057

The conclusion that we may draw from these computations is that observers have little to fear from anomalous refraction. Its mean effect, at a properly chosen station, appears to be considerably less than the accidental errors of observation in the best work that can be done at the present time. Accordingly, this explanation for inconsistencies in meridian work should be advanced with caution. The present paper also throws light upon the nature of KIMURA's phenomenon; this, it will be remembered, is a small term in the latitude variation and is independent of the longitude. Our computations indicate, if they do not indeed prove, that this term is real, and is not due (as has been suggested) to anomalous refraction.

ALLEGHENY OBSERVATORY, December 22, 1905.

VARIABLE STAR NOTES.

BY ROSE O'HALLORAN.

U Cassiopeiæ.

On September 17, 24, and October 15, 1905, this variable was invisible in a four-inch telescope. The maximum predicted for November 3d was looked for, and according to the following observations occurred somewhat later.

1905. October 23, 26—Of 12th magnitude. November 3—About 11.7; dimmer than *g*.[1] November 13—Between *g* and

[1] For comparison-stars, see chart, *Publications* A. S. P. No. 98, p. 209.

e. November 18—Brighter than *g* or *f;* equal to *e.* November 20—Brighter than *e* or *d;* less than *c.*

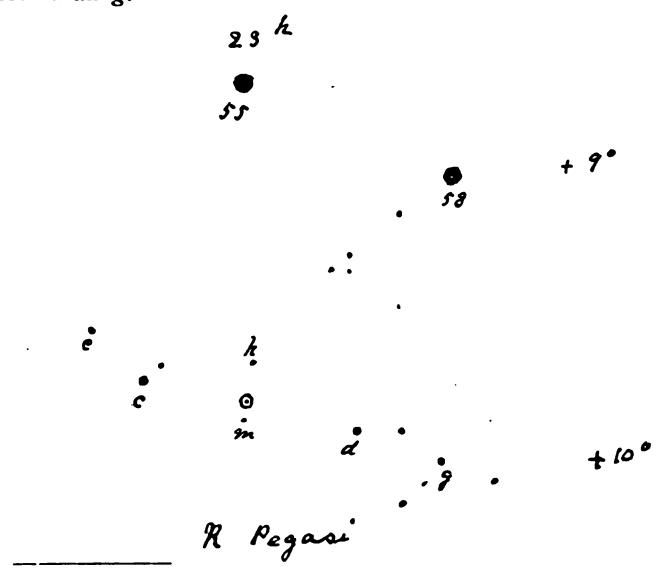
V Cassiopeiæ.

This variable having risen to maximum in the middle of August, 1904, declined gradually, and on October 19th was only equal to the star of 10.5 magnitude about half a minute of arc preceding. On November 15th of the same year it had sunk to invisibility. September 17, 1905, it was of about 10th magnitude, being distinctly brighter than the above-mentioned star closely preceding, and on the 24th was still brighter, though about half a magnitude less than *e* in the star chart.[1]

1905. October 10—Equals *d.* October 15—Between *d* and *b.* October 23—Equals *b.* November 3, 13, 20—Equals *b.*

R Pegasi.

1904. September 12—Brighter than *g;* equals *d;* less than *c.* September 29—Between *d* and *c.* October 30—Nearer to the light of *g* than of *d.* November 6, 8—About two tenths brighter than *g.* November 27, December 2—Equals *g;* brighter than *h.* December 4—Between *g* and *h.* December 17—Equals *h;* less than *g.*



[1] See *Publications* A. S. P. No. 98, p. 209.

1905. January 2—Between *h* and *m;* nearer to *m.* September 17, 24, 26, October 15—Equal to *d;* less than *c.* October 25—Brighter than *h;* equals *g.* November 18, 20, 24—Between *h* and *g.* December 3—About midway between *h* and *g.* December 21—Less than *h;* scarcely brighter than *m.* December 28—Fainter than *m* (night very clear).

The period is about 380 days, and maxima were predicted for September, 1904 and 1905.

U Herculis.

1904. May 8, 10, 14, 16—Equal to *f.* June 2, 10—Three tenths dimmer than *f.*

1905. May 5, 9, 19, 21—Equal to *c;* brighter than *d.* May 29—The same (night clear and dark). June 5, 10—Between *c* and *d.* June 17—Equals *d*; brighter than *f.* June 22, 27—Less than *d;* equals *e;* brighter than *f.* July 1—Between *e* and *f.* July 5—Scarcely brighter than *f.*

U Hercules

The accompanying chart shows the position of this variable with regard to *Gamma* in the arm of *Hercules.* The scarcity of telescopic stars in the field of view makes identification easy, and the range from about 7 to 12 magnitude places each phase within the reach of small instruments. Its long period of thirteen months is subject to periodic inequality.

I Ursæ Majoris.

1905. January 27—Brighter than *h;* less than *f.* February 22—Equals *c;* brighter than *e.* March 26—Equals *e;* brighter

than *f* or *g*. April 4—Between *e* and *f*. April 21—Between *f* and *k;* nearer to *f*.

S Boötis.

1904. May 2, 16—Invisible.

1905. April 4—Equal to *g;* brighter than *h*. April 27—Brighter than *f* or *g;* equals *e;* less than *c*. May 4, 9—The same (May 7 was the date of predicted maximum). May 19—Between *e* and *c*. May 21—It seems nearer to the luster of *c* than of *e*. July 1—It has sunk to about 11.5 magnitude.

S Ursæ Majoris.

The comparison-stars used for this variable and also for *I Ursæ Majoris* and *S Boötis* are those of the charts published by the Harvard Observatory in 1891.

1904. February 16—Invisible. April 4—Equals *f*. April 17—Equals *g*.

1905. January 9—Very close to the brightness of *d*, perhaps two tenths less; brighter than *g;* less than *c* (night clear). January 24, 27—The same. February 22—Two tenths brighter than *f*. March 26—Equals *h*. April 4—Less than *h* or *l;* of about 11 magnitude. April 21—Not discernible (night hazy).

A four-inch refractor was used for these observations.

SAN FRANCISCO, December 30, 1905.

TOTAL SOLAR ECLIPSES.

SKETCH OF AN APPARATUS FOR INVESTIGATING THE POSITION OF THE PRODUCING ELEMENTS OF THE SHADOW-BANDS IN SPACE.

BY M. ROSO DE LUNA.

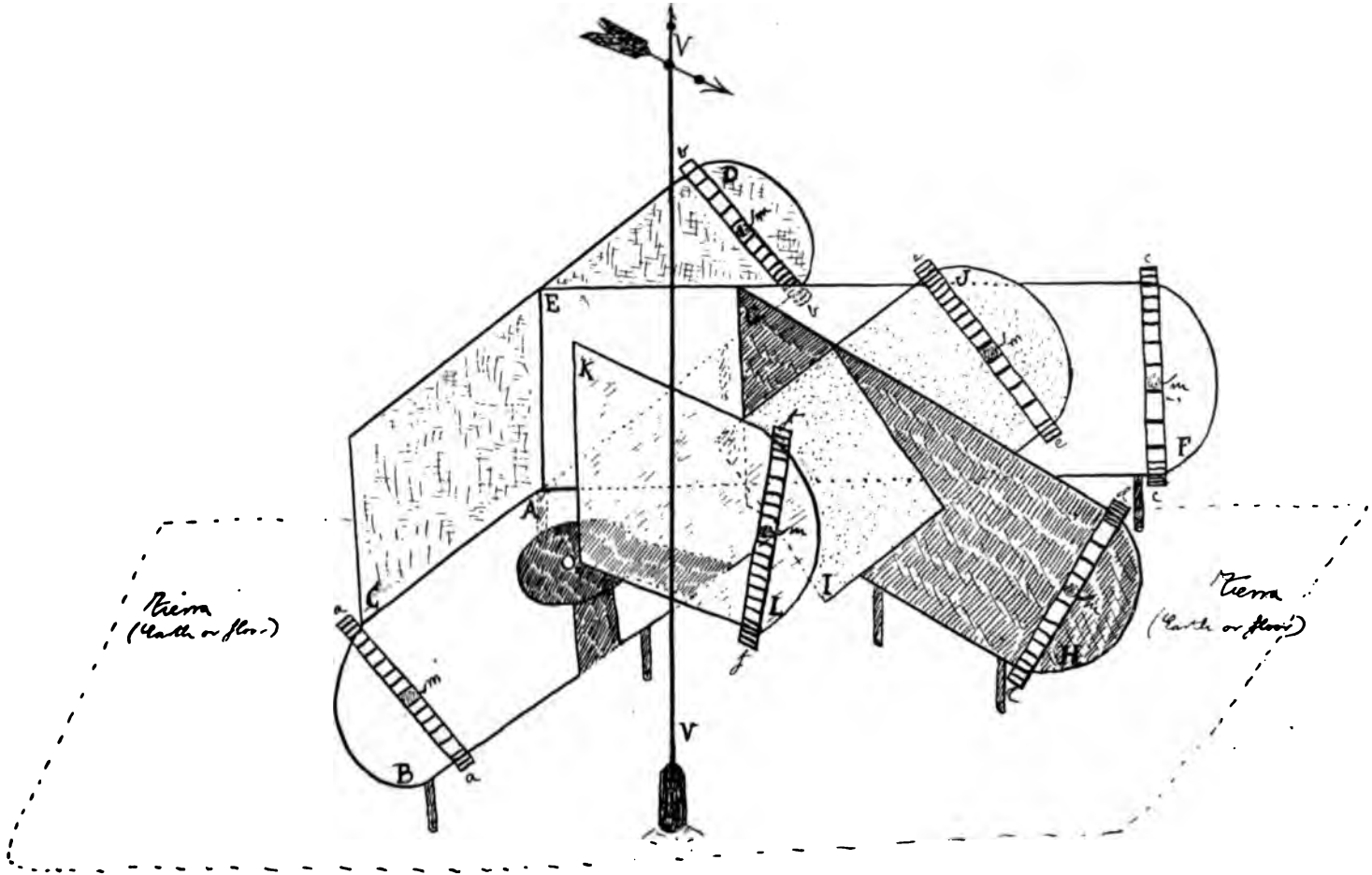
It is known that some moments before and after the total phase of an eclipse we can see sinuous bands sliding along the ground, which alternately are bright and dark. The orientation, direction of movement, speed, etc., of these bands have been studied by means of a white piece of linen laid horizontally on the ground and placed from north to south. From

observations thus made Messrs. F. H. BIGELOW and W. H. PICKERING have made important studies as to the possible causes of the phenomenon. I now propose to men of science to conduct the observations in future eclipses by geometrically searching for the position in space of the producing elements of such bands; or, perhaps, they may have a luni-solar origin, owing to the decomposition effected by the edges of the Moon upon the rays of the thin solar sickle at the proximities of totality.

To determine the position of such elements, three different planes with two (one vertical and another horizontal), as per descriptive geometry, would be enough. That is the method followed by us of determining in the eclipse of August 30, 1905, at Soria, Spain, the position of said elements, which were found to be in a plane nearly vertical (88° to 99° in 5 seconds), forming with the observation vertical plane, placed from east to west, an angle less than 45°. From these observations we have deduced the great convenience of employing several other planes on which to mark the traces of the undulating bands, and our apparatus to observe the eclipse in 1912 will be constituted (see figure), first, of a horizontal plane, A B, at the height of the arms of the observer, who will be situated at O; second, the vertical plane, C D, placed from north to south; third, another vertical plane, E F, from east to west; fourth, another, G H, azimuthal to the Sun at the moment of totality; fifth, another, I J, perpendicular to the latter; sixth, another, K L, in the direction of the wind, moved by the weathercock, V, which may be made immovable at the moment of observation. The observer, at O, will mark in all these planes the respective orientation of the bands at least once before and once after the total phase.

In the prolongation of these planes will be placed six observers, who will mark the said orientation of the bands, each in his respective plane, as a check on the observations.

Six other observers will measure the width of the bright parts between the bands by comparison with the respective *scale ribbons aa, bb, cc, dd, ee, ff.* Each of these ribbons is mounted upon two rollers forming an endless chain. The rollers are so mounted that the ribbons may easily be placed perpendicularly to the bands.


V
D
E
K
A
C
B
J
F
L
I
H
V
Tierra
(Earth or floor)
Tierra
(Earth or floor)

In the linen scale-ribbon are drawn black bands measuring 2^{cm}, separated by increasing series from 2 to 30^{cm}. The zones coinciding in width with the separation-zones will be marked with a pencil between the bands. Two other observers will measure the width of the bands by comparison with a pasteboard with painted bands separated by one half centimeter. Another six could study the coloration of the bands by means of special pasteboards with painted bands in several colors, black, earthy, gray, etc.

With the data of the first seven observers, and the geometrical studies of every two or every three of the six planes, we shall have all the necessary elements to geometrically calculate the position in space of the generating elements of the undulating bands, and we shall be able to advance most confidently conclusions about the true cause of so interesting a phenomenon.

MADRID, September 3, 1905.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1906.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter,	Mar.	3,	1h	28m	A.M.	First Quarter,	April	1, 8h 2m A.M.
Full Moon,	"	10,	12	17	P.M.	Full Moon,	"	8, 10 12 P.M.
Last Quarter,	"	17,	3	57	A.M.	Last Quarter,	"	15, 12 36 P.M.
New Moon,	"	24,	3	52	P.M.	New Moon,	"	23, 8 6 A.M.

The vernal equinox, the time when the Sun crosses the equator from south to north and spring begins, is on March 21st, 5 A. M. Pacific time.

Mercury is an evening star on March 1st, but is too near the Sun to be seen, setting only a little more than half an hour after sunset. The distance from the Sun increases rapidly; by the middle of the month the planet remains above the horizon more than an hour and a half after sunset, and can be easily seen in the evening twilight for a week or more before and

after that date. It reaches its greatest eastern elongation (18° 31′) on March 18th. This greatest elongation is much smaller than the average, as *Mercury* is at the time only six days from perihelion, having passed that point on March 12th. After passing greatest elongation the planet draws near the Sun, passing conjunction and becoming a morning star on April 4th. After that, it recedes from the Sun, and by the end of the month has nearly reached greatest west elongation. It will then rise a little less than an hour before sunrise, and may possibly be seen in the morning twilight. On March 27th *Venus* and *Mercury* are in conjunction, the latter being 4° 46′ north. They are, however, rather too near the Sun at the time to be easily seen.

Venus passed superior conjunction with the Sun and became an evening star on February 13th, but does not get far enough away from the Sun to be easily seen until after the middle of March. On April 1st it remains above the horizon about an hour after sunset, and this interval is increased about half an hour during the month. Its greater brightness, even in its present unfavorable position, allows it to be seen much nearer the Sun than is the case with *Mercury*. Toward the close of the month *Venus, Mars,* and *Jupiter* are all in the same quarter of the heavens in the order of distance from the Sun as named, but none of the three reach conjunction with each other until May.

Mars is also an evening star, and sets a little earlier than during January and February,—at 8:58 P. M. on March 1st and at 8:40 P.M. on April 30th. Its apparent distance from the Sun diminishes from 35° on March 1st to 19° on April 28th, and it moves 42° eastward and 14° northward among the stars from *Pisces* through *Aries* and into *Taurus*. At the end of April it lies between the *Pleiades* and the first-magnitude red star *Aldebaran,* the brightest star in the constellation *Taurus*. Its actual distance from the Earth is still increasing, although not as rapidly as it has for some months, and the increase will continue at a diminishing rate until the latter part of July. By the end of April its brightness will be within about twenty per cent of the minimum; but it will still be brighter than the Pole Star and may be seen as long as it remains above the horizon, somewhat more than an hour after sunset.

Jupiter is still an evening star, rather farther from the Sun than the others already mentioned. It does not set until after midnight on March 1st, and at the end of April it remains above the horizon until after 9 o'clock. It is in the constellation *Taurus,* and during March and April moves 11° eastward and 2° northward. On March 1st it is a little south of the *Pleiades,* and at the end of April it is about 5° north of *Aldebaran, α Tauri.*

Saturn passed conjunction with the Sun on February 24th and became a morning star, but does not move far enough away from the Sun to be seen in the morning twilight until nearly the end of March. On April 1st it rises about an hour before sunrise, and on April 30th a little more than two hours before the Sun. Toward the end of April the planet is far to the south of the Sun, and its rising point on the horizon is about 30° south of that of the Sun. The rising point of the planet changes slowly, while that of the Sun moves rapidly northward during the spring.

Uranus is a morning star, rising at about 3:30 A. M. on March 1st and at about 11:30 P. M. on April 30th. It is in quadrature with the Sun—that is, at right angles to it as seen from the Earth—on March 29th. It is in the constellation *Sagittarius* a short distance north of the milk-dipper group, moves about 1° eastward until April 13th, and then begins to move slowly westward. There is no bright star near enough to make identification easy.

Neptune is in almost exactly the opposite part of the sky, being above the horizon, while *Uranus* is below. It is in the constellation *Gemini* several degrees west and south of *Castor* and *Pollux,* the principal stars of the constellation. It is far too faint to be seen without the aid of a telescope.

(FIFTIETH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to MICHEL GIACOBINI, Astronomer,

Nice, France, for his discovery of an unexpected comet on March 26, 1905.

Committee on the Comet-Medal:
W. W. CAMPBELL,
WM. H. CROCKER,
CHAS. BURCKHALTER.

SAN FRANCISCO, January 11, 1906.

(FIFTY-FIRST) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to EMIL SCHAER, Astronomer, Geneva, Switzerland, for his discovery of an unexpected comet on November 17, 1905.

Committee on the Comet-Medal:
W. W. CAMPBELL,
WM. H. CROCKER,
CHAS. BURCKHALTER.

SAN FRANCISCO, January 11, 1906.

(FIFTY-SECOND) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to MICHEL GIACOBINI, Astronomer, Nice, France, for his discovery of an unexpected comet on December 6, 1905.

Committee on the Comet-Medal:
W. W. CAMPBELL,
WM. H. CROCKER,
CHAS. BURCKHALTER.

SAN FRANCISCO, January 11, 1906.

NOTES FROM PACIFIC COAST OBSERVATORIES.

A Programme of Solar Research.[1]

The following programme of solar research has been prepared for the Solar Observatory:—

I. DIRECT PHOTOGRAPHY.

(*a*) Daily photographs of the Sun on a scale of 6.7 inches (17^{cm}) to the diameter, for comparison with the spectroheliograph plates.

(*b*) Large scale photographs of spots and other regions, for the study of details.

II. PHOTOGRAPHIC STUDIES OF THE SOLAR ATMOSPHERE WITH THE SPECTROHELIOGRAPH.

(*a*) Daily photographs of the Sun with the lines:—

(1) H_1, showing the calcium flocculi at low level.

(2) H_2, showing the calcium flocculi at higher level.

(3) H_2, showing the calcium flocculi at higher level and the prominences (composite photographs, with separate exposures for flocculi and prominences).

(4) *Hδ*, showing the hydrogen flocculi.

(5) Other dark lines, as may prove feasible, showing the flocculi of the corresponding elements.[2]

(*b*) Measurement and discussion of the above photographs, involving:—

(1) Determination of the area of the flocculi and their distribution in heliographic latitude and longitude. These results will give a measure of the relative activity of different elements in various regions of the solar surface; furnish the means of answering certain questions regarding the relationship of flocculi to spots, such as the time of first appear-

[1] Abstract of *Contributions from the Solar Observatory*, No. 3.

[2] λ 4045, showing the iron flocculi, is now used daily.

ance, relative position on the disk, etc.; and serve for comparison with meteorological and magnetic records.

(2) Measurement of the heliocentric position of points in the flocculi that can be identified on several successive photographs, to determine the law of the solar rotation for the corresponding elements.

(3) Determination of the position, area, and brightness of eruptive phenomena, to find whether they are related to other phenomena of flocculi or spots, to possible changes in the absorption of the solar atmosphere, and to auroras and magnetic storms.

(4) Measurement of the area and brightness of the neutral or bright regions near sun-spots, on photographs of the hydrogen flocculi, for comparison with other phenomena, such as the velocity of ascending and descending currents of calcium vapor, the radiation (for given wave-lengths) of the spots and neighboring regions, etc.

(5) Study of the motion of the high-level calcium vapor, especially in flocculi overhanging sun-spots, to determine the direction and velocity of horizontal currents.

(6) Measurement of the position and area of prominences, and study of their relationship to solar and terrestrial phenomena.

(*c*) Special studies with spectroheliographs of suitable dispersion, involving the use of various dark lines (including enhanced lines) and of lines affected in spots; simultaneous photographs of eruptions on the disk in different lines; comparative studies of quiescent and eruptive prominences with the hydrogen and calcium lines, etc.

III. SPECTROSCOPIC INVESTIGATIONS.

(*a*) Daily photographs of the spectra of spots, region $H\alpha$ to $H\beta$, for the determination of intensities and the identification of lines that are widened or otherwise affected.[1]

[1] These photographs may also chance to record such exceptional phenomena as the remarkable disturbance of the reversing layer described in a previous paper (*Astrophysical Journal*, Vol. XVI, 220, 1902).

(*b*) Photographs of the H (or K) line, with high dispersion, on successive sections of the disk, to give the radial velocity of the calcium vapor in the flocculi, chromosphere, and prominences.

(*c*) Measurements with the bolometer of the relative radiation, corresponding to various wave-lengths, of the sun-spots and photosphere, and bolographs of spot spectra.

(*d*) Spectrographic measurements of the solar rotation, to determine the law of rotation with the lines of various elements, and to detect possible changes in the rotation period. (See also II (*b*), 2.)

(*e*) Miscellaneous investigations, as opportunity may offer, of the spectrum of the chromosphere; the pressure in the solar atmosphere, etc.

IV. STUDIES OF THE TOTAL SOLAR RADIATION.

(*a*) Frequent determinations of the total solar radiation, involving measures with the pyrheliometer at various altitudes of the Sun, and simultaneous bolographic records to give the absorption of the Earth's atmosphere.

(*b*) Frequent determinations of the absorption of the solar atmosphere for light of various wave-lengths, to detect any possible changes in absorption that might account for observed changes in the total radiation.

(*c*) Occasional supplementary observations on Mt. San Antonio (24½ miles = 39.4^{km} from Mt. Wilson) at an altitude of 10,100 feet (3,500^{m}).

(*d*) A comparative study of different types of pyrheliometers.

V. LABORATORY INVESTIGATIONS.

(*a*) A study of the lines affected in sun-spots under various conditions of temperature, pressure, etc.

(*b*) Determinations of the pressure shifts of certain solar lines.

(*c*) Other similar investigations.

With a few exceptions, these investigations are now in progress at the Solar Observatory. Direct photographs of the Sun are taken daily, but large-scale photographs of details have not yet been started. The daily spectroheliograph routine includes H_1, H_2, $H\delta$, and λ 4045 (Fe) photographs of the disk, and H_2 (composite) photographs of the flocculi and prominences, all on a scale of 6.7 inches to the Sun's diameter.

(See *Contributions* No. 7.) Special studies with the spectroheliograph are also in progress. An account of the work on spot spectra and on the motion of the calcium vapor may be found in *Contributions* Nos. 5 and 6. Special apparatus for the spectrographic study of the solar rotation has been nearly completed in our instrument-shop. The study of the solar radiation has so far been confined to the investigations of the Smithsonian expedition (June-November, 1905), but arrangements have been made to continue this work next year. Laboratory researches will be undertaken shortly with instruments which are now being installed.

GEORGE E. HALE.

SOLAR OBSERVATORY.

FIRST CATALOGUE OF SPECTROSCOPIC BINARIES.[1]

The application of the Doppler-Fizeau principle to the study of the stars, by photographic means, has led to the discovery of an entirely new class of stellar systems, known as spectroscopic binaries. This term is in general applied to those stars which are apparently single when viewed through our most powerful telescopes, but which the spectrograph has shown to be accompanied by invisible companions. However, the condition that the companions shall be invisible is too limited, and it is more satisfactory to class with the spectroscopic binaries all stars whose radial velocities have been observed to vary. The discovery of the first spectroscopic binary, *ζ Ursæ Majoris,* was made by Professor PICKERING in 1889. The objective-prism spectrograms of this star showed that it consisted of two components, approximately equal in brightness, in rapid revolution around their center of mass. The second discovery, made by Professor VOGEL from plates secured with a slit spectrograph, related to *Algol* and the massive and relatively very dark companion which partially occults the bright primary, for terrestrial observers, once each revolution. In successive years additions to the list were made by PICKERING, VOGEL, BELOPOLSKY, Miss MAURY, Mrs. FLEMING, and BAILEY, until, in the summer of 1898, thirteen spectroscopic binaries were known. Since that date the number has increased with great rapidity. The systems observed up

[1] Extract from the *Lick Observatory Bulletin* No. 79.

to January 1, 1905, numbered one hundred and forty. A tabulation of these by observatories may be of interest.

Lick Observatory (Mills spectrograph)	58
Lick Observatory (D. O. Mills expedition to the Southern Hemisphere)	14
Yerkes Observatory (Bruce spectrograph)	41
Harvard College Observatory	8
Lowell Observatory	7
Pulkova Observatory	6
Potsdam Observatory	4
Meudon Observatory	2
Cambridge Observatory	1
Visual binaries observed radially, but without variation	6
	147
Deduct for binaries independently discovered at two observatories	7
Total	140

The literature concerning the discovery, observation, and study of these systems is quite widely scattered, and the requirements of the work with the Mills spectrograph have led us to collect and tabulate the data. The time appears to have arrived when their publication, in a form which we venture to entitle a "First Catalogue of Spectroscopic Binaries," will prove useful to many investigators in this and other departments of astronomy.

[The catalogue, covering eight quarto pages of tabular matter, is here omitted.]

Strictly speaking, the six stars, α_1 – α_2 *Geminorum*, γ *Leonis*, γ *Virginis*, α *Centauri*, 61 *Cygni*, and δ *Equulei*, have not yet been observed as spectroscopic binaries. The *differences* of the radial speeds of their components have been measured, but these differences have not been observed to vary. However, their inclusion is a convenience and, we think, unobjectionable. While every visual binary carries the possibility of measurement as a spectroscopic binary, the number of such stars available for observation in the near future is limited, and all such may well be placed upon the spectrographic observing-list.

The number of spectroscopic binary systems not resolvable by our powerful telescopes is relatively very large. Of the

stars studied with the Mills spectrograph, at least one in seven seems to be an invisible binary of short period. For the *"Orion"* type of stars, observed especially with the Bruce spectrograph, the remarkable proportion of one in three was found.

Only those systems have been detected whose periods are relatively short, and for which the variations of radial speed are considerable. The smallest observed variation is that of *Polaris,*—six kilometers per second. Had the variation for *Polaris* been only one kilometer, it would no doubt have escaped detection. Such a variation could be measured by present instruments and methods; but this range would not have excited the observer's suspicion, and the discovery would have remained for the future. It is probable that there are more systems with variations of speed under six kilometers than there are with larger ones; and all such are awaiting discovery. The velocity of our Sun through space varies slightly, because it is attended by companions,—very minute ones compared with the invisible bodies discovered in spectroscopic binary systems. It is revolving around the center of mass of itself and its planets and their moons. Its orbit around this center is small, and the orbital speed very slight. The total range of speed is but three one-hundredths of a kilometer per second. An observer favorably situated in another system, provided with instruments enabling him to measure speeds with absolute accuracy, could detect this variation, and in time say that our Sun is attended by planets. At present, terrestrial observers have not the power to measure such minute variations. As the accuracy attainable improves with experience, the proportional number of spectroscopic binaries discovered will undoubtedly be enormously increased. In fact, the star which seems not to be attended by dark companions may be the rare exception. There is the further possibility that the stars attended by massive companions, rather than by small planets, are in a decided majority; suggesting, at least, that our solar system may prove to be an extreme type of system, rather than a common or average type.

The number of spectroscopic binaries discoverable by present means is certainly a large proportion of the stars brighter than the eighth photographic magnitude. This is about the present limit for successful observation. It must be remem-

bered that in a spectrum the light is spread over a large area. The recording of the spectrum of a ninth-magnitude star, using moderate dispersion, is perhaps comparable with photographing a twentieth-magnitude star by means of our powerful reflecting telescopes. Further, the successful measurement of moderate dispersion spectrograms requires that the image be of good intensity and that the observational conditions be favorable.

In any given list of stars the number of binaries discoverable by spectrographic means seems to exceed greatly the number observable visually. Messrs. HUSSEY and AITKEN have found that of stars brighter than the ninth magnitude, one in eighteen is double in the 36-inch refractor, with components less than 5″ apart. This limit of 5″ represents in general a continually increasing linear separation of the components as we pass to fainter and fainter stars. The ability of the spectrograph to resolve close pairs, on the other hand, is independent of their distances from us, provided they supply sufficient light for accurate observation and their spectra contain measurable lines.

The companions of binaries discovered by means of the spectrograph have not been observed visually in our powerful telescopes, although they have been carefully searched for. They may be so close to the principal star that, viewed from our distance, the two images cannot be resolved. The separation of the components is probably less than one hundredth of a second of arc for most of the binaries thus far announced. Again, for very few of the systems are the spectra of both components recorded. This does not establish that the companion is a dark body, but only that it is at least one or two photographic magnitudes fainter than the primary. The fourth-magnitude companion of a second-magnitude star would scarcely be able to impress its lines upon the primary's spectrum. The invisible components in many spectrographic binaries might be conspicuous stars if they stood alone.

It is evident that future catalogues of spectroscopic binaries will contain thousands of entries. It will be neither possible nor desirable for them to include the observational data. Mainly for this reason we have decided in the present catalogue to let references to the original publication suffice in nearly all cases.

The blank spaces in the columns of orbital elements emphasize the strong need for work in that direction. There can be little doubt that a comparative study of spectroscopic orbits and of spectroscopic and visual orbits would be most fruitful of results.

W. W. CAMPBELL,
HEBER D. CURTIS.

THE SPECTROGRAPHIC BINARY, Y *OPHIUCHI*.

During the summer and fall of 1905 a good series of spectrograms of the variable star Y *Ophiuchi* were obtained with the one-prism spectrograph. The plates thus far measured and reduced give a velocity-curve of double amplitude of about 20^{km} and a period coinciding with the period of light variation, which is 17.12 days. The minimum velocity seems to occur about two days after the epoch of light-maximum.

January 25, 1906. SEB. ALBRECHT.

NOTE ON THE RECENT OBSERVATIONS OF THE RADIAL VELOCITY OF α *DRACONIS*.

α	$14^h\ 1^m.7$	Type A	Vis. magn. 3.6
δ	$+64°\ 51'$		Photo. magn. 4.0

α *Draconis* was announced as a spectroscopic binary by Director CAMPBELL and Dr. H. D. CURTIS in 1903 (*L. O. Bulletin* No. 46) from an observation of its radial velocity in 1902, and two in 1903. The first plate of June 16, 1902, gave a velocity of $\pm 0^{km}$, while the plates of April 29th and May 4th gave velocities of -43^{km} and -42^{km}, respectively. Three plates have been obtained since the above, the measures of which, made by the author, are as follows:—

Plate.	Date.	Velocity.
3272B	1904 June 19	-42^{km}
3831B	1905 June 13	-42
4152E	1906 January 4	-40

Director CAMPBELL has asked me to call attention to the fact that our recent measures agree among themselves, and with those of April 29 and May 4, 1903, so that the binary character of α *Draconis* rests upon the plate of June 16, 1902. The velocity from this plate is based upon the magnesium line 4481, which is slightly out of focus. Repeated measures by

several observers make it improbable that the velocity of $\pm$ 0^{km} is in error as much as 5^{km}. We have also taken every means at hand to assure ourselves that this plate is not that of some other star.

January 25, 1906. J. H. MOORE.

THE SPECTROSCOPIC BINARY λ *HYDRÆ*.

α 10^h 5^m.7 Type K Vis. magn. 3.8
δ — 11° 51′ Photo. magn. 4.9

The binary character of λ *Hydræ* was suspected by Mr. W. H. WRIGHT from observations of its radial velocity in 1898, 1899, and 1900, and confirmed by the recent measures of Mr. K. BURNS.

The following is a list of good plates, and their measures obtained with the Mills spectrograph:—

Plate.	Date.	Velocity.	Measured by
686A	1898 March 30	23.3	WRIGHT.
1174D	1899 Feb. 13	22.9	"
1648C	1900 Feb. 2	18.6	"
1660A	Feb. 26	19.4	"
1661D	March 9	18.4	"
1675B	March 12	19.2	"
1682C	March 13	19.0	"
1694C	March 27	19.2	"
1967D	Dec. 5	15.1	BURNS.
2010D	1901 Jan. 15	17.4	REESE.
2321D	Dec. 23	21.4	"
2627C	1902 Dec. 31	24.1	BURNS.
2706D	1903 Feb. 23	22.5	"
3186A	1904 March 31	19.9	BRASCH.
		18.0	MOORE.

Unfortunately the plates are not distributed in such a manner as to give a good determination of the period.

January 25, 1906. J. H. MOORE.

ECLIPSES OF SATELLITES OF *JUPITER*.

The following eclipse phenomena of *Jupiter's* satellites were observed here with the 12-inch refractor and its 3-inch finder. The powers used were: 12-inch, 155, except in cases indicated

in column "Remarks"; 3-inch, 18.5. Dr. AITKEN kindly secured the observations of December 22d and 29th in my absence. The times recorded are the latest or earliest moment at which the satellite was certainly seen. Very few eclipse disappearances and reappearances of Satellite I, observable at Mt. Hamilton since 1905, October 15th, were missed.

Phenomenon.	Am. Eph. and N. A. Wash. M. T.	Observed Wash. M. T. 12-inch.	Observed Wash. M. T. 3-inch.	Remarks.
Ec. Dis.	1905 h m s	h m s	h m s	
I	Oct. 19, 18 38 11	Before 38 37	18 38 07	0.8 of *Jupiter's* disk occulted by cross-wires of finder.
I	21, 13 06 43	.....	13 05 58	12″, power 64; "I easily seen nearly a minute later"; time not recorded.
III	23, 12 03 00	12 05 58	12 04 34	12″, power 64.
I	26, 20 32 34	Before 32 55	20 32 00	Seeing very good. 12″, power 64.
II	27, 12 31 00	12 33 55	12 32 37	Finder, glimpsed at 49ˢ?
I	Nov. 6, 11 24 23	11 24 37	11 23 42	Poor conditions. 12″, glimpsed at 39ˢ?
III	6, 20 02 57	20 09 50	20 08 09	12″, power 64.
I	13, 13 19 06	13 19 13	13 18 48	Seeing poor. Finder time late? 12″ slightly out of focus.
I	18, 20 45 11	20 45 12	.....	Seeing poor. I not seen in finder, though observation started at 20:41.7. Ec. Dis. close to disk of planet.
I	20, 15 13 58	At or slightly before 13 55	.....	High N.W. wind, but seeing fair. Driving clock stopped. I not seen in finder. Observation started at 15:10.5. Ec. Dis. close to disk.
I	22, 9 42 38	9 42 24	.....	Seeing fair till 9:42:24 when door was opened and seeing became extremely poor. Would probably have been seen 3ˢ longer. Observation began at about 9:36. I not seen in finder, though at about 9:38, 0.8 of *Jupiter's* disk was occulted by cross-wires. Ec. Dis. very close to disk.
Ec. Re.				
I	Dec. 1, 8 15 01	.....	8 18 41	Seeing very poor after storm. Observation difficult.
I	6, 15 41 23	15 40 30	15 41 31	Seeing fairly good. 12″, time probably 2ˢ or 3ˢ late.
I	8, 10 10 17	10 09 24	10 10 18	Finder, 18ˢ? Seeing variable. Air steady at 18ˢ? Easily seen at 42ˢ.
I	22, 14 01 10	14 00 11	14 02 16	Observer. R. G. A. Poor seeing.
I	29, 15 56 45	15 55 57	15 57 09	Observer, R. G. A.
	1906			
I	Jan. 23, 10 41 55	10 42 13	10 42 47	Seeing fair. Times late? I seen with ease at times recorded.
I	30, 12 37 45	12 36 58	12 37 44	Good conditions.

January 31, 1906. JAMES D. MADDRILL.

Nova Aquilæ No. 2.

A single magnitude observation of *Nova Aquilæ*, made December 16th, completes my series for 1905. (See these *Publications*, October and December.) Further measures cannot be made here till the latter part of February.

The estimates were made with the 12-inch, power 155, by the Argelander method, at a large hour-angle ($5^h.1$) under poor atmospheric conditions. Four photometric settings on the star *f*, with the 12-inch, November 25th, gave for its magnitude 13.46.

G. M. T., 1905.	Estimates.	*Nova.*
Dec. $16^d.60$	*e* 5–6 *x* 3 *Nova* 12 *f*; *d* 8 *e* 8 *Nova*	$12^m.1$

The value of a step from this observation is $0^m.085$.

January 25, 1906. JAMES D. MADDRILL.

Rainfall at Mt. Hamilton.

Until the 9th of January the season beginning 1905, July, threatened to be a dry one. From January 11th to 19th, however, almost continuous rain brought the season record up from 4.93 inches to 17.23 inches. The heaviest fall

In one hour was 0.77^{in}, from 12:40 to 1:40 P. M., January 12th.

In 24 consecutive hours was 3.86^{in}, from 3 P. M., January 11th, to 3 P. M., January 12th.

Of the latter 3.39 inches fell in the last 12 hours. The next day the fall

In 24 consecutive hours was 3.83^{in}, from 6 A. M., January 13th, to 6 A. M., January 14th.

Of this 3.61 inches fell in 12 hours, from 7 A. M. to 7 P. M.

The twenty-five-year summary at the conclusion of this article shows that about 14.5 inches are to be expected by January 19th; hence we are about 2.7 inches ahead of the normal season.

A table of the rainfall by months for the first twelve years, 1880, July – 1892, June, was compiled by Mr. PERRINE in 1893 and published in these *Publications* (Vol. V, p. 126). The following table is a continuation to 1905, June; and a summary

in the last two columns based on all the rainfall data for the twenty-five years.

Melted snow is included with rain.

Month.	1892 1893	1893 1894	1894 1895	1895 1896	1896 1897	1897 1898	1898 1899	1899 1900
	in.	in.	in.	in.	in.	in.	in.	in.
July	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.12
September ..	0.24	0.48	1.64	0.08	0.47	0.07	0.29	0.00
October	1.38	0.66	2.98	0.78	1.85	1.25	1.33	6.37
November ...	10.30	4.01	0.84	2.46	5.86	1.51	1.23	4.92
December ...	5.56	3.58	11.90	3.16	4.91	2.70	2.13	4.16
January	3.29	9.74	10.00	9.54	3.50	2.30	5.63	3.26
February	3.45	10.52	3.08	1.08	7.42	4.16	0.75	1.70
March	8.99	2.54	1.46	3.83	6.45	2.04	11.11	3.37
April	3.61	0.89	2.30	6.70	0.82	0.84	1.40	4.06
May	0.95	2.78	2.39	2.10	0.28	2.41	1.47	1.35
June	0.16	0.64	0.00	0.02	0.38	0.38	0.39	0.00
Annual	37.93	35.84	36.61	29.76	32.22	17.66	25.73	29.31

Month.	1900 1901	1901 1902	1902 1903	1903 1904	1904 1905	25-year Mean.	Mean Sum to End of Month.
	in.	in.	in	in.	in.	in.	in.
July	0.01	0.00	0.00	0.00	0.00	0.00	0.00
August	0.02	0.05	0.00	0.00	0.05	0.03	0.03
September ..	0.08	1.08	0.00	0.00	2.33	0.41	0.44
October	3.48	2.19	2.09	0.47	2.51	1.82	2.26
November ...	7.76	2.89	3.01	7.69	2.05	3.01	5.27
December ...	2.21	1.61	3.11	1.39	3.84	6.53	11.80
January	5.76	1.44	8.86	1.98	4.04	4.67	16.47
February	5.92	9.15	2.20	9.53	3.89	4.72	21.19
March	1.98	5.18	9.89	8.06	5.91	5.39	26.58
April	3.33	2.60	1.12	4.38	1.36	3.11	29.69
May	1.07	1.19	0.05	0.45	2.27	1.63	31.32
June	0.02	0.00	0.00	0.03	0.00	0.38	31.70
Annual	31.64	27.38	30.33	33.98	28.25	31.70	

January 22, 1906. JAMES D. MADDRILL.

A DOUBLE-STAR PROBLEM.

BURNHAM has called 95 *Ceti* (= ALVAN CLARK 2) "the most mysterious and strange double star in the heavens. I have tried it," he says, "first and last, perhaps hundreds of times with apertures all the way from 6 to 36 inches without

being able to see any trace of the little star." He did, however, measure it on two nights in 1888.

My own experience confirms BURNHAM'S estimate of the mysterious nature of this system, and it is one object of the present note to add another chapter to its history. My second object is to show that this star is not in a class by itself by giving some observations of three other stars, two, at least, of which present very similar difficulties to those encountered in the attempt to harmonize the observations of 95 *Ceti*.

These three stars are 80 *Tauri* (= Σ 554), *Draconis* 205 (= β 971), and β 163 (Ll.41386); and my recent measures of them and of 95 *Ceti* are:—

95 *Ceti*.

Date.	Angle.	Distance.	Magnitudes.		Telescope.
1898.15	136°.7	0″.51	6—9	2ⁿ	12-inch and 36-inch

1900 and 1901. Companion not seen on four nights with the 36-inch telescope, the seeing being very good.

1904.93. Companion invisible with 36-inch telescope. Seeing good. 2ⁿ.

1906.014	166°.6	0″.48	6—9+	1ⁿ	36-inch

Σ 554.

1904.9. Star round on many nights and no companion seen with 36-inch. Special pains taken because of Professor HUSSEY'S discovery of a difficult pair near by (See Hu. 1080). Professor HUSSEY, too, could see no companion to Σ 554.

1905.994	44°.9	0″.57	6—9	36-inch	Seeing 3
1906.014	38 .0	0 .55	6—9	36-inch	Seeing 4

β 971.

1900.749	8°.0	0″.37	6.5—9	36-inch	1ⁿ	Seeing 3
1902.315	29 .3	0 .34	6.0—9.5	36-inch	1	Seeing 2+

1904.44[1] Star single. Powers to 1500 on 36-inch. Several good nights.

1905.288	36 .6	0 .37	6—9	36-inch	Seeing 2+

1905.458 to 1905.751. Star single on four good nights. 36-inch.

[1] Professor HUSSEY also found this star single in 1904 with the 36-inch telescope.

β 163.

1898.74 253°.2 0″.63 7—9.6 12-inch 3ⁿ

1905, July and August. No companion seen with the 36-inch on many nights—some of them excellent. Star identified with certainty, and on one good night all neighboring stars to the magnitude 9.0 carefully examined.

95 *Ceti* was discovered by ALVAN CLARK in 1853 with a 7½-inch refractor, and was first measured by DAWES in 1854. The positive measures to date are:—

1854.80	71°.9	0″.73±	DAWES (3 nights).
1888.77	112 .8	0 .45	BURNHAM (2 nights).
1897.83	147 .8	0 .46	SEE and BOOTHROYD (1 night).
1898.15	136 .7	0 .51	AITKEN (2 nights).
1899.82	157 .0	0 .35	SEE (2 nights).
1906.01	166 .6	0 .48	AITKEN (1 night).

80 *Tauri* was first measured by STRUVE in 1831, the mean of four nights' measures being 12°.9 and 1″.74. The measures of the next thirty years indicated only very slow motion, DEMBOWSKI in 1862 obtaining 9°.6 and 1″.13 from four nights' measures. But when BURNHAM measured it in 1878 the distance had diminished to 0″.58, with hardly any change in the angle. This is the last measure published. After this time no one seems to have examined the star until 1890, when BURNHAM failed to see the companion with the 36-inch telescope. Since then many attempts have been made to observe the companion with the same telescope, but all without success until my two very recent measures.

In his General Catalogue of his own discoveries BURNHAM gives all the measures of β 971 and β 163 to 1899. The following are sufficient to show the history of these stars:—

β 971.

1879.88	354°.7	0″.54	6.5—8.5	2ⁿ	BURNHAM.
1891.48	4 .5	0 .36	6.8—9.2	3	"
1893.54	107 .0	0 .25±	.....	2	LEAVENWORTH.
1894.61	Single 36-inch		.....	2	BARNARD.
1897.43	11 .6	0 .30	.....	1	LEWIS.
1898.70	5 .2	0 .36	6.5—9.0	1	AITKEN.

β 163.

1876.09	252°.3	1″.15	7.1 — 9.0	4ⁿ	DEMBOWSKI.
1891.52	254 .6	0 .75	7.2 — 9.8	3	BURNHAM.
1895.46	251 .9	0 .56	.....	5	SCHIAPARELLI.

It will be noted that the four systems are similar in point of the relative magnitudes of their components, and, in a general way, in point of their angular separation (excluding the early measures of Σ 554 and of β 163). If we had to deal with only one star, or one observer, or one telescope, it would not be difficult to suggest plausible explanations for the negative results. As it is, it seems hardly credible that the failures to see the fainter stars can be due to poor seeing. In my own case my records show that other close and unequal pairs, including some exceedingly difficult ones, were measured on the nights when negative results were obtained for the four named. Nor does it seem at all possible, except perhaps in the case of β 163, that the angular separation of these pairs was too small to permit the companion to be seen on so many different dates. The positive measures seem to exclude this explanation.

Of course, we may fall back upon the hypothesis of variability in the light of the companion-star; but one hesitates to advance that explanation in the absence of any positive observations of variability. There seems to be no reason in the nature of things why the component of a binary system should not be variable as well as any single star, but it has too often proved in the past that the suspected variability of a double star has been due simply to poor seeing or to a poor telescope. For the present, therefore, the problem remains, and adds to the interest of these systems.

R. G. AITKEN.

January, 1906.

SOME TESTS OF THE SNOW TELESCOPE.[1]

In the preliminary tests of the Snow telescope at the Yerkes Observatory, the results were rather disappointing, though good images were occasionally obtained. It was evident that difficulty might be expected from the distortion of the mirrors

[1] Abstract of *Contributions from the Solar Observatory*, No. 4.

by the Sun's heat, and in the first experiments on Mt. Wilson this expectation was realized. Soon after the exposure of the mirrors to the Sun it was seen that the focal length was increasing, and, as the focus changed, evidence of the astigmatism of the mirrors made itself apparent in the appearance of the image inside and outside the focal plane. Since the change of focus amounted in some cases to as much as twelve inches (30.4^{cm}), and since the astigmatism under such circumstances was very marked, it was feared that great difficulty would be experienced in the use of the telescope, particularly as the focus at the opposite limbs of the Sun on one occasion differed by as much as three inches (7.6^{cm}). The change of focal length at different times did not seem to be the same, even for equal altitudes of the Sun. This was soon traced to the change in the amount of heat absorbed by the mirror as the silver film deteriorated in use. Another variable, as subsequent experiments proved, was introduced by the strength of the wind and the temperature of the air blown across the mirror surface. On a day with a cool breeze the focus changed less than on a day with no wind. Naturally enough, the height of the Sun above the horizon proved to be a very important factor, so that the focus changed much more rapidly near noon than early in the morning.

From the outset, the advantages of observing the Sun during the early morning hours had been apparent. In view of the difficulties that were being experienced, this point was again carefully investigated, and it was soon found that with the Snow telescope the finest definition is to be expected about one hour after sunrise. At this time the mountain is but little heated, and the atmospheric absorption reduces the intensity of the solar radiation to such a degree that the mirrors change their figure slowly. If the mirrors are shielded from sunlight between exposures of photographs, and if the exposure time is made as short as possible, excellent results can be obtained during a period of about an hour in the early morning, and usually during a similar period not long before sunset.

It must be understood that the precautions mentioned are necessary only when it is desired to secure the finest possible definition of the solar image. When such precautions are used, the average photographs taken during the summer in the early

morning with the Snow telescope and temporary spectroheliograph are but little inferior to the best photographs, secured on only a few days in the year, with the 40-inch Yerkes telescope and the Rumford spectroheliograph. The best photographs taken on Mt. Wilson are distinctly superior to the best ever secured by Mr. ELLERMAN and myself with the 40-inch telescope. Unless these points were made clear, it might be supposed that no work could be done with the Snow telescope except under the conditions stated. As a matter of fact, however, very fair photographs can be obtained with the spectroheliograph at almost any time during a cool day, and in the early morning and late afternoon hours of a hot day without wind. It is only necessary to arrange the daily programme of observations so that the spectroheliograph, which requires the finest definition, is used during the period when the seeing is best. Photographic work on the spectra of sun-spots follows, and after this is completed the conditions are entirely satisfactory for various other observations, such as bolographic work on the absorption of the solar atmosphere, etc.

The ventilated house provided for the Snow telescope has proved so satisfactory that it has not seemed necessary to make further experiments on the use of Langley's method of stirring the air along the path of the beam. It is usually found best to lower the inner canvas wall on the side of the house away from the Sun, leaving the canvas wall on the opposite side of the house in place, so that the heated air under the louvers may pass upward and out through the ventilated roof, instead of entering the house and disturbing the beam.

While fans have not been employed for stirring the air, they have nevertheless been used to advantage in blowing the mirrors, for the purpose of preventing a rapid change of figure. In the first experiments, a fan four feet in diameter, driven by an electric motor, was mounted at the south end of the cœlostat pier. Air from this fan was led to the cœlostat mirror and the second mirror through large canvas tubes. In these experiments the concave mirror did not receive a blast of air, as it was thought the effect could be detected sufficiently well if only the first and second mirrors were cooled in this way. As it was found that the focus could be varied through a considerable range by blowing the first two mirrors, arrange-

ments have been made to cool all the mirrors in the same way. The small electric fans to be used for this purpose will be operated while the adjustments of the spectroheliograph are being made, and also between exposures, when the mirrors are shielded from the Sun by an adjustable canvas screen.

Excellent definition is obtained at night with the Snow telescope, except when the mirrors have been exposed to the Sun for some hours during the afternoon. On such occasions the rapid change of figure during the early evening results in irregular distortions, as indicated by the multiple images sometimes observed. Without such previous exposure to the Sun, the images of the stars and of the Moon leave nothing to be desired. Nevertheless there is a considerable change of focal length during the night, but this would be inappreciable during short exposures, and during long exposures on stellar spectra it is only necessary to correct the focus by changing the position of the concave mirror from time to time.

From a mechanical standpoint the Snow telescope has proved to be completely successful. From an optical standpoint it has shown itself capable of giving results with the spectroheliograph superior to those obtained in our work with the 40-inch refractor. In view of the advantages it offers for many classes of astrophysical research, this telescope may now be considered to have passed the experimental stage, though the possibility of providing better material for the mirrors indicates that its optical performance will probably be considerably improved in the future.

GEORGE E. HALE.

SOLAR OBSERVATORY.

PHOTOGRAPHIC OBSERVATIONS OF THE SPECTRA OF SUN-SPOTS.[1]

(1) Our photographs of the spectra of sun-spots clearly record the strengthened and weakened lines, and can be advantageously used in place of visual observations.

(2) Table I gives the intensities on the photographs of the principal lines in the region λ 5000 – λ 5850.

(3) Table II shows that nearly three quarters of these lines are identified in ROWLAND'S table, and thus fails to support

[1] Summary of results given in *Contributions from the Solar Observatory*, No. 5.

LOCKYER'S conclusion that at sun-spot maximum most of the known lines in spots are replaced by lines of unknown origin.

(4) All of the silicon lines in the region studied are much weakened, while other substances have only a small proportion of weakened lines.

(5) Table III gives the measured wave-lengths of the faint ("band") lines photographed in the region $\lambda 5030 - \lambda 5215$. Comparison with ROWLAND'S table shows that these lines, which are considerably strengthened in spots, correspond with the extremely faint lines of the solar spectrum.

(6) A review of the literature indicates that these lines are the ones seen visually by YOUNG, DUNÉR, and others who have resolved the general absorption in spots, and that they account for most, if not all, of the so-called "bands."

(7) Our results confirm YOUNG'S conclusions that the absorption in sun-spots is due to gaseous matter, and not to solid or liquid particles.

(8) After discussing the views of EVERSHED and WILSON on the cause of the darkness of sun-spots, we conclude that it may be sufficiently well accounted for by absorption alone.

GEORGE E. HALE AND WALTER S. ADAMS.
SOLAR OBSERVATORY.

COLOR OF THE SHADOWS OF *JUPITER'S* SATELLITES PROJECTED ON THE DISK OF THE PLANET.

On the evening of December 23, 1905, I was showing the visitors *Jupiter* through the large refractor. The seeing was good and the sky clear. The shadows of satellites I and III were on the disk of the planet. The shadow of I fell upon the dark-red equatorial belt of the planet near the meridian, just northwest of the great red spot; the shadow of III had just entered upon the disk very near the south pole of the planet.

It was at once seen that the two shadows were not equally dark. The shadow of III was a dense black, while that of I was not completely devoid of color. The character of the backgrounds was quite different, that upon which the shadow of I was projected being several shades darker than the white, cloudy region upon which the shadow of III fell. The effect of contrast would be, of course, to make the shadow which fell upon the brightest region (III) appear the darkest. The

shadows were, however, of appreciable size, so that it was possible to study them to some extent as *surfaces* and not as mere *points*. Then, too, the shadow of III was much larger than that of I, which should tend to reduce somewhat the effect of contrast. The difference of brightness in the backgrounds was carefully considered at the time of observation, and, after making what was considered an ample allowance for any such effect, the shadow of I appeared to have a decidedly more brownish color than the shadow of III.

Powers of 270 and 520 were used. The latter power, especially, gave the shadows sufficiently large disks for me to feel very certain of the color in that of I, and to feel equally certain that the blackness of III was real. The difficulty of properly interpreting such an observation is fully recognized.

It is seldom that the shadows of two of the satellites fall together upon favorable portions of the planet's surface for such an observation as the above. My reason for publishing this single observation is to call it to the attention of observers having the use of large telescopes, in the hope that they may take advantage of any opportunity to compare the density of the shadows of any of the satellites.

There can be little doubt of the absence of sensible atmosphere upon the Jovian satellites, and in that event any light in their shadows would have an important bearing on the physical condition of *Jupiter*. Such a condition, if established, would go far toward proving the high internal temperature of that planet and explaining the rosy color of the equatorial belts.

MT. HAMILTON, January 25, 1906. C. D. PERRINE.

THE SIXTH AND SEVENTH SATELLITES OF *JUPITER* AT THE OPPOSITION OF 1905-1906.

The sixth satellite was first observed, at the present opposition, on July 24th by Mr. ALBRECHT, Fellow in Astronomy at the Lick Observatory, with the Crossley reflector. He had the assistance of Mr. ELLIOT SMITH, also Fellow at the Observatory.

The satellite was then in position-angle 56°.6 and at a distance of 26'.0 from its primary. A comparison with Dr. Ross's ephemeris, printed in *L. O. Bulletin* No. 78, indicated a lengthening of his period to 251 days and small corrections

to the other elements. This satellite reached west elongation about October 1, 1905, and at present is passing eastern elongation. This is the fourth elongation reached since its discovery.

It is now known that this satellite, as well as the seventh, is revolving about *Jupiter* in the same direction as the other satellites of the Jovian system,—i. e. the motion is direct.

An approximate reduction of the observation of January 4th gives the following residuals from Dr. Ross's revised ephemeris in *A. N.* No. 4042:—

Position-angle (Obs. — Eph.)	+ 0°.4
Distance (Obs. — Eph.)	— 0'.4

This is a close agreement, when the approximate nature of the ephemeris and observation is considered.

The seventh satellite was first reobserved on August 7th by Mr. ALBRECHT, using the Crossley reflector. Its position-angle was 289°.7 and distance 54'.6. A comparison of this position with Ross's ephemeris published in *L. O. Bulletin* No. 82 shows that the satellite was over a month in advance of its predicted place. On October 24th, however, it was only about a week in advance of its ephemeris place. This condition, taken in connection with the fact that western elongation was at a much greater distance than predicted, indicates that the eccentricity is much larger than 0.02, Dr. Ross's value.

Western elongation was reached about September 6th at a distance of over 61' (for distance unity of *Jupiter*). Observations are scattering for nearly two months past, owing to stormy weather, but those available indicate that eastern elongation was passed the latter part of December at a distance of only 43'. This would give 0.18 as the minimum value of the eccentricity. As there are good reasons for believing that the major axis is considerably inclined to the normal to the line of sight, the eccentricity is probably larger than 0.18.

At the time of discovery, early in January, 1905, the seventh satellite had passed western elongation and was moving eastward. Since that time it has passed three elongations, one of which was not observed on account of the proximity of the Sun.

In the case of an orbit of such large eccentricity, it is not satisfactory to try to determine the period from the elongation times available. It is certain, however, that the period of the

seventh satellite will not differ greatly from that of the sixth, whose orbit is much better known at present.

The apparent orbit of the sixth satellite has opened out very much since discovery, while that of the seventh has closed up, so that during the present opposition the Earth is almost exactly in the plane of its orbit. These facts also prove conclusively that the motions of both satellites about their primary are direct. C. D. PERRINE.

MT. HAMILTON, January 25, 1906.

ORBIT OF THE SIXTH SATELLITE OF *JUPITER*.

On account of the accuracy with which this orbit is representing recent observations, it is thought advisable to reprint the elements for the benefit of *A. S. P.* readers. The orbit and ephemeris were derived by Dr. F. E. Ross, of the Carnegie Institution, Washington, D. C. C. D. P.

ELEMENTS REFERRED TO THE EARTH'S EQUATOR.

Mean jovicentric right ascension.....	289°.1		1905.0 Gr. M. T.
Right ascension of perijove.....	270		
Right ascension of node on equator...	176 .7		
Inclination to equator	5	29′	
Semi-major axis (at *Jupiter's* mean distance)		50′.6	
Tropical mean motion		1°.435	
Period		251 days	
Eccentricity		0.156	

EPHEMERIS FOR GREENWICH MEAN NOON.

1906.	Position Angle.	Distance.
February 1	99°	60′
6	97	59
11	94	58
16	92	57
21	90	55
26	88	53
March 3	85	50
8	82	47
13	79	43
18	75	39
23	71	35
28	65	31

COMING TOTAL ECLIPSES OF THE SUN.

A total eclipse of the Sun will occur on January 13, 1907. It will begin at sunrise at a point about midway between Moscow and the north end of the Caspian Sea. The shadow will pass over the northern end of the Caspian Sea, the southern end of the Aral Sea, midway between the cities of Samarkand and Taschkent, over eastern Turkestan, Mongolia, near the boundary between Transbaikal and Manchuria, and end at sunset on the mainland northwest of Saghalin. It would seem that the only location worth considering for an observing-station would be in the Samarkand-Taschkent region, longitude 68° E., latitude 40° N., where the duration of totality would be two minutes. The difficulties of transport for observers, instruments, and supplies would be practically prohibitive, especially in the middle of the winter season. The Lick Observatory will not send an expedition to observe this eclipse.

A total eclipse of the Sun will occur on January 3, 1908. Its path will cross the central Pacific Ocean, from west to east. The total phase begins at sunrise at longitude 155° E. and latitude 11° N. At local noon the shadow will be at 145° W., 12° S. The total phase will end at sunset at 85° E., 10° N., near Punta Arenas, Costa Rica, Central America. The shadow does not pass over any islands of considerable extent, but it is probable that several quite small islands lie within its borders, especially along the western half of the path. From Hydrographic Office Chart No. 1980 and other information kindly supplied at my request by Superintendent O. H. TITTMANN, of the U. S. Coast and Geodetic Survey, it appears that Flint Island is well situated.

"Flint Island (British), discovered in 1801, lies in latitude 11° 26′ S., longitude 151° 48′ W., is 13 feet high, covered with brushwood and trees, and is visible from the masthead from a distance of 16 miles. It is about 2½ miles long N. N. W. and S. S. E., half a mile wide, and is fringed by a steep coral reef, which dries at low water, and extends seaward generally about half a cable, but off the northern end of the island it extends seaward 4½ cables and off the southern end E. S. S. 2½ cables. In the interior are two small lagoons of brackish water. . . . There is little or no rise and fall of tide at Flint Island. The landing is very bad even for surf-boats, but it is said to export nearly 200 tons of copra annually."—Extract from Superintendent Tittmann's letter.

For this longitude, 151° 48′ W., the corresponding latitude of the center of the eclipse path is 11° 17′ S. The island thus appears to be within ten miles of the central line. As the shadow-path will be about ninety-three miles wide, this location would be comparatively close to the center. It is not probable that the assigned latitude is seriously in error. Any possible error in the assigned longitude would hardly be serious, for the shadow will travel nearly east and west. The motion in longitude will be six times that in latitude.

The duration of totality at Flint Island, from American Ephemeris data, would be 4^m 0^s.

The next total eclipse of the Sun observable in the United States will take place on June 8, 1918. It will pass from the northwest coast of Washington to Florida during the latter half of the summer afternoon.

Another total eclipse, occurring on September 10, 1923, will enter the coast of California at latitude about 36° in the early afternoon, and will pass over the Gulf of Mexico and southwestern Cuba. W. W. CAMPBELL.

NOTE ON COMET *c* 1905 (GIACOBINI).

The third comet of the year 1905 was discovered December 6th by GIACOBINI at Nice. At the time of discovery it was 21° north of the equator in Right Ascension 14^h 22^m. Since then it has been traveling southeasterly toward the Sun. Its closest approach to the Sun will be on the 22d of this month, when it will be within twenty million miles of that body. Its closest approach to the Earth was on the 6th of January, when it was distant about one hundred million miles. The plane of its orbit is inclined 43° to the plane of the ecliptic. The orbit is parabolic.

Because of the very near approach to the Sun this comet becomes very bright at the end of January. At the present date it is visible to the unaided eye a few moments before sunrise. It will pass the Sun and become an evening object on the 23d inst. By the 28th it will set about half an hour after the Sun, and will be 7° south of it. On this date it should be easily seen with the unaided eye, when it will be thirty times brighter than at discovery. After the first of February its brightness will diminish rapidly.

Two sets of elements and ephemerides for this comet have been derived by LEUSCHNER's "short method" by the writer, with the assistance of Mr. A. J. CHAMPREUX. These may be found in Lick Observatory *Bulletins* Nos. 87 and 88.

RUSSELL TRACY CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT, January 17, 1906.

PHOTOGRAPHS OF COMET *c* 1905.

Comet *c* 1905 was photographed at the Lick Observatory on nine different dates preceding its perihelion passage. The first photograph was taken on December 23, 1905, when the comet was comparatively faint and no suggestion of a tail was visible in the observing telescope. When the plate was developed the comet was found to have a tail extending several degrees from the nucleus. On account of stormy weather it was impossible to secure another photograph until December 28th. By this time the comet had become very much brighter, the tail being easily visible in the guiding telescope. This plate showed a tail extending a distance of eight or ten degrees from the nucleus, and much detail in its structure was brought out.

Subsequent plates recorded many changes in the structure of the tail, and gave evidence of rapid motion in the material composing it. The exposure times varied from half an hour to an hour, depending upon weather conditions and the position of the comet.

Besides the plates described above a series of trail plates was taken, from which it is hoped data of value may be obtained concerning the variation in brightness of the comet's nucleus.

At a later date the plates will be studied in detail. In the mean time a more extensive series may be secured. The comet has passed perihelion, and will soon be an evening object for telescopic observation.

January, 1906. ELLIOTT SMITH.

NOTE ON THE COMETS DISCOVERED AT THE LOWELL OBSERVATORY.

A telegram was received at the Lick Observatory on the evening of December 14, 1905, from Professor E. C. PICKERING

at the Harvard College Observatory, announcing that Mr. SLIPHER, at the Lowell Observatory, had discovered a comet by photography on November 29, 1905, in the position R. A. $22^h\ 44^m$; Decl. $-11°\ 18'$. No data were given as to the rate or direction of motion; hence, in view of the time interval since its discovery, it did not seem worth while to search the sky for this object.

Professor PICKERING'S astronomical bulletin, received a week later, stated that "the comet was moving 4′ per hour in a direction 15° north of west." It would be interesting to know how this direction was determined, since a trail on a single photographic plate would leave it ambiguous.

Another astronomical bulletin, received on December 29th, stated that Professor LOWELL had discovered a second comet on the same photographic plate in the position R. A. $22^h\ 34^m$; Decl. $-8°.7$, just to the northwest of Σ 2935. This object was moving 2′ per hour in a direction south by west or north by east, and had two tails.

The discovery of a comet by photography is unusual enough to be noteworthy, but to find two on a single plate is a unique achievement. It is unfortunate that these discoveries could not be announced in time to be verified by visual observations. It might be suggested that photographic defects often look wonderfully like comet trails; but it is of course assumed that Professor LOWELL took precautions to guard against such deception before announcing the discoveries.

January, 1906. R. G. AITKEN.

COMET *a* 1906 (BROOKS).

The first comet of the year was discovered by BROOKS, of Geneva, New York, on the night of January 26th, in R. A. $16^h\ 19^m.5$, and Decl. $+47°\ 10'$. Observations were secured by the writer on the following three nights and an orbit was computed at the Students' Observatory by Dr. CRAWFORD and Mr. CHAMPREUX. The comet was found to be moving in a practically parabolic orbit. According to the ephemeris, it will pass within about 5° of the north pole on February 18th.

It is a fairly easy object in a 3-inch telescope on a dark night. The nucleus as seen in the 12-inch seems about equal

in brightness to an eleventh-magnitude star. I have suspected the presence of a tail in position-angle about 300°.

JAMES D. MADDRILL.

CHANGES IN THE PERSONNEL OF THE D. O. MILLS EXPEDITION TO THE SOUTHERN HEMISPHERE.

Dr. H. K. PALMER, Assistant in the D. O. Mills Observatory on Cerro San Cristobal, Santiago, Chile, returned to California in November. He left Santiago in September, after a residence of two years and six months there, and on the return journey made an extensive trip through the interior of northern Chile and the highlands of Peru, including a visit to the Harvard College Observatory at Arequipa. Dr. PALMER is at present engaged at Mt. Hamilton in measuring the spectrograms secured by the expedition.

Acting Astronomer HEBER D. CURTIS, accompanied by his family, sailed from San Francisco on December 30th, via Panama, to Chile, to take charge of the D. O. Mills Observatory for a period of five years. Their absence from Mt. Hamilton is a severe loss to the personal side of life here.

Mr. MILLS has very generously provided also for extensive improvements in and additions to the equipment. The dome, formerly covered with heavy painted canvas, will be recovered with thick tin or with iron. A ball thrust bearing and two roller side bearings will be provided for the declination axis of the telescope. Apparatus for quick resilvering of the 37-inch mirror will be constructed. Telephone connection between the observatory on the summit and the astronomer's residence in the city will be made. A building will be constructed on the summit to accommodate a machine-shop equipped with lathe and small tools driven by electricity, and to contain rooms for the observers. Two-prism and one-prism spectrographs are under construction, in order that radial-velocity determinations may be carried to fainter stars. Professor WRIGHT, in charge of the expedition in the past, has shown that certain rapid changes in focal length and other sources of disturbance in the stellar images are due to rapid changes of temperature in the mirror during the first hours of the night. The question of artificially maintaining the temperature of large mirrors during the daytime at the reading estimated for the atmos-

phere for the evening that follows has often been discussed in past years by the members of our staff and by others. During my absence in Europe last summer and fall Dr. CURTIS worked out the details for such a refrigerating scheme, and it will be tried on San Cristobal. Various other minor improvements will be made at once. Dr. CURTIS expects to reach Santiago about February 15th.

Immediately following Dr. CURTIS's arrival, Acting Astronomer W. H. WRIGHT and Mrs. WRIGHT will return to Mt. Hamilton. Professor WRIGHT's original appointment for duty in Chile terminated in October, two years after the observatory was ready for work. Dr. CURTIS's duties in connection with the eclipse expedition to Labrador, however, prevented him from leaving earlier for the south, and Mr. WRIGHT has remained there awaiting his arrival.

An assistant in the D. O. Mills Observatory will soon be appointed in succession to Dr. PALMER.

W. W. CAMPBELL.

NOTES FROM THE BERKELEY ASTRONOMICAL DEPARTMENT.

Professor LEUSCHNER was present at the recent meeting of the Astronomical and Astrophysical Society of America, held in New York City. He presented the following papers by members of the Berkeley Astronomical Department:—

"An Analytical Method of Determining the Orbits of Satellites." A. O. LEUSCHNER.

"On the Orbit of the Seventh Satellite of *Jupiter*." R. T. CRAWFORD, A. J. CHAMPREUX.

"A Contribution on Astronomical Refraction." R. T. CRAWFORD.

"Tables for the Reduction of Photographic Measures."

"Investigation of the Repsold Measuring Apparatus of the Student's Observatory." B. L. NEWKIRK.

Mr. STURLA EINARSON has been appointed Assistant in Practical Astronomy in the Berkeley Astronomical Department. Mr. EINARSON took the A. B. degree at the University of Minnesota last year, and will continue his study at the University of California.

CORRIGENDUM.

In No. 105 of these *Publications*, page 195, line 3, for $-38'\ 25''$, read $+2'\ 12''$. R. T. C.

HONORS FOR MEMBERS OF THE LICK OBSERVATORY STAFF.

The honorary degree of Doctor of Science was conferred upon Director CAMPBELL by the University of Michigan at the annual commencement, June 22, 1905. Dr. CAMPBELL was present to receive the degree.

The Royal Astronomical Society has awarded its gold medal to Director CAMPBELL for his "spectroscopic researches, which have greatly increased our knowledge of stellar motions."

The Astronomical Society of Mexico conferred a gold medal and diploma upon Astronomer PERRINE in December, 1905, in recognition of his discovery of the sixth and seventh satellites of *Jupiter*. R. G. A.

GENERAL NOTES.

Definitive Orbit of Comet 1844II (MAUVAIS).—A definitive orbit of this comet has been published, in a supplement to the *Astronomische Nachrichten,* by FRANK E. Ross, Ph.D., a former student in astronomy at the University of California and Fellow at the Lick Observatory. Dr. Ross starts with an orbit by PLANTAMOUR, published in 1847, reduces the observations, computes the perturbations by *Venus,* Earth, *Saturn,* and *Jupiter,* and corrects PLANTAMOUR'S elements. The agreement between theory and observation is decidedly improved, the corrected orbit passing through all but one of the normal positions within about two seconds of arc.

Two Articles on Cometary Motion.—A recent number of the *Publications* contained a note on stationary meteor-radiants in which the question of the origin of comets and meteors was referred to. It is probable that some of these bodies are strangers from the depths of space, to which they return after a single visit to the Sun's system. Others are known to be moving in elliptic orbits, and so, temporarily at least, to belong to the solar family. Comets approaching the Sun on nearly parabolic orbits have suffered perturbations which have added them to the class of "periodic" comets, and in the case of LEXELL'S lost comet the period was shortened by one approach to *Jupiter,* only to be lengthened again a few years later by a second approach to the same planet.

Any theory to account for the origin of comets and meteors must be based upon or include answers to the two questions: Are most of the orbits originally elliptic or hyperbolic? Are the elliptic orbits stable, or will perturbations some day change the elliptic orbits into hyperbolic ones?

Number 4058 of the *Astronomische Nachrichten* contains "A Theorem Regarding Comet Perturbations," by Dr. ELIS STROEMGREN, which makes an important contribution to the methods used in gaining data for the answer to the first question. He gives an abridged method for determining by mechanical integration the perturbation of the major axis of an elliptical comet-orbit from the date of osculation backwards

as far as is necessary for the subsequent investigations, and produces an expression for the upper limit of the total perturbation of the major axis from the beginning of the perturbative effect until the time to which the perturbation is thus carried back. The length of the interval during which the process of mechanical integration must be employed depends upon the eccentricity of the original orbit, being longer the less this eccentricity differs from unity.

The December number of the *Bulletin Astronomique* contains a memoir by M. H. v. ZEIPEL, "On the Instability of the Movement of the Comets," which has an important bearing upon the answer to the second of the above questions. He considers first an ideal case in which two bodies move in circular orbits about their common center of gravity, a third body of negligible mass having entered this system and been captured by it. Although the planets do not move in circles, the orbits of the greater planets are, roughly speaking, not far from circular, and the first system treated by v. ZEIPEL may be regarded as a fair approximation to the state of affairs in the solar system when a comet, entering the system on a hyperbolic orbit, is "captured" by the perturbations of one of the major planets. He shows that in this ideal case the captured comet would at some future time be expelled from the system.

Taking up the more general case when the two chief bodies of such a three-body system move in ellipses, v. ZEIPEL shows that the third body of negligible mass (supposed to have been captured as comets may be captured by the major planets) would at some future time be expelled, except in certain exceptional cases, whose occurrence is infinitely improbable.

This theorem follows also as a corollary to the discussion by POINCARÉ at the close of chapter XXVI of his *Méchanique Céleste,* though no mention is made there of an application to periodic comets.

It is to be remembered that these theories take no account of the chances of collision between the comet and one of the other bodies.

These theorems regarding the expulsion of third bodies entering a system of two bodies furnish foundation for a con-

viction that if the periodic comets are really visitors from the outside universe they will some day be expelled through the perturbations of the body that captured them, provided they are not first disintegrated by close approach to (or collision with) some of the members of the solar system. It is, however, improbable that the comets are, in general, strangers from outer space, visiting the solar system for the first time. Out of several hundred cometary orbits that have been computed, not more than a half-dozen show evidence of being hyperbolic, and in these instances the evidence is inconclusive.

If the comets were really visitors in the Sun's system, having had no previous connection with it, we should expect to find most of their orbits decidedly hyperbolic. If the three or four hundred comets entering on nearly parabolic orbits are visitors in the sense above indicated, their original motion in space must have been the same in direction and velocity as that of the Sun's system. In other words, the velocity of these bodies with respect to the Sun must have been zero. The stars are in motion with reference to the Sun's system, and with an average velocity of some twenty miles a second. We should expect the same thing to be true of smaller bodies moving independently through space,—namely, that their velocities with respect to the Sun would be some twenty miles per second. That the original motion of the cometary masses was identical in magnitude and direction with that of the Sun certainly argues some connection with the solar system, possibly of the sort referred to in the note on stationary meteor-radiants above mentioned. B. L. N.

A Test of a Transit Micrometer. By JOHN F. HAYFORD. *Report of the U. S. Coast and Geodetic Survey*, 1904, App. No. 8; pp. 453-487, two plates. Separate. Washington, 1904. —In this interesting and important monograph the author presents to that portion of the American scientific public which does not keep in touch with scientific progress in foreign lands a new method of observing star transits—a method which, we may confidently assert, is to revolutionize that art. The old or present method consists essentially in noting the time when the moving star-image in the focus of a telescope crosses a fixed line. In this radically new method, on the other hand,

the observer maintains a steady bisection of the star-image on a movable micrometer-thread, while the electric signals are made on the chronograph automatically by the rotating micrometer-head.

The peculiar piece of apparatus required for this operation was first successfully devised and constructed by Dr. J. REPSOLD, of Hamburg, in 1889, and may be adapted to any form of transit instrument. It is called in English the "Transit Micrometer." To those familiar with the work of the German observers who have already made use of Dr. REPSOLD's device through a number of years there could be no question of the marked superiority of the new method.

The author's particular purpose, however, was to investigate, in behalf of the U. S. Coast and Geodetic Survey, the desirability of applying the new micrometer to the straight type of transit instrument now and hitherto in use by the Survey, with the view of improving its determinations of longitude. This he has done in a thorough manner, with the aid of Mr. E. G. FISCHER, of the Survey, who devised a transit micrometer for use in the experiments and as a model for possible adoption by the Survey. Mr. FISCHER contributes also a clear and full description of the micrometer, so that the reader, with the aid of the two large plates, can understand the apparatus in all its details. The only material difference from REPSOLD's design is, that an ingenious provision is made for cutting out the automatic signals except in just that part of the field where they are wanted. Mr. HAYFORD presents the results of the experimental observations and their discussion in a complete manner and in a very clear style. He made about one half of the observations himself, starting with no previous experience with this kind of work; and he called in the services of fifteen other observers, whom he divides into four classes, from those with experience in astronomical observing and in good training to those who had had little experience with instruments of precision of any sort or at any time. By this *a fortiori* method he demonstrates the superiority of the transit micrometer; and while some of the work seems to the astronomical reader very crude for publication and the professional feels somewhat aggrieved at this public introduction of neophytes into his sacred domain, it

must be remembered that Mr. HAYFORD is in the position of having to make a special plea.

With his good instrument and this medley of observers, Mr. HAYFORD shows, among other conclusions:—

1. That the relative personal equation, that bugbear of astronomers in determining star positions and terrestrial longitudes practically vanishes,—that is, it is less than $0^s.050$ in any case.

2. That he is justified in predicting that three nights of observing by the new method and without exchange of observers will serve to determine a longitude as accurately as ten nights of observing by the old method including an exchange of observers—a great economy of time and transportation.

3. That, for a practiced observer, the new method is truly equivalent to maintaining bisection upon a stationary point of light, and that the absolute or angular accidental error of observation is the same for all stars throughout the range of declination.

4. That good observations can be secured without previous practice.

5. That, owing to the rapidity with which the automatic signals can be recorded, a greater number of stars can be observed in a given time. The author states that his observing-list contained sixteen stars per hour to ten stars per hour in the customary lists of the Survey.

Mr. HAYFORD'S fourth conclusion, as given above, when we consider the immense advantages of the method, is not so extravagant as it seems. However, the author would of course prefer an observer at the outset at least accustomed to the manipulation of delicate instruments. As the author notes, the remarks of observers at beginning plainly indicate their perturbation of mind as well as of hand in attempting to following a fast-moving star. But the persistent observer may be assured that some fine night there will come the satisfaction of seeing the star-images "go to sleep" on the apparently stationary thread. Mr. HAYFORD remarks that more practice simply reduces the accidental error by about twenty-five per cent. The present writer has had some experience with the new micrometer on a larger instrument. He found that his

probable error of a single star-signal started at $\pm 0^s.07$ after observing a number of stars, and became $\pm 0^s.030$, under favorable conditions, after considerable practice scattered over a number of months, or the same as for the old key method. As in the making of a telescopic objective, it is the last stages of improvement that take by far the most time and care.

In this connection, also, it may be remarked that Mr. HAYFORD calls attention, in the course of his discussion, to two or three "curious facts" which cropped out in the course of his investigations; but he does not mention the fact, as shown in his Table V, that one observer, belonging to his very lowest class, takes the prize in the form of the smallest probable error of a single observation of a star,—not a large amount of data involved, it is true, but more than for some of the other observers. Ladies always catch the largest fish in camping-parties, and here a young woman seems to incur the smallest error.

It should be admitted that all the advantages are not with the new micrometer; though its disadvantages, so far as seen, concern only the physical comfort of the observer, especially in cold weather. With the old method one could wear heavy gloves, but would hardly attempt to do so while turning a delicate micrometer. With the old method eye and hand could enjoy little intervals of rest between threads, while with the new both must be kept steadily at work; but this is modified if one is content with a short series of many signals close together, and with long practice the feeling of intense strain wears away. Still, it is the writer's experience that any unexpected noise or incident is more disturbing than with the old method. But, of course, such incidents rarely occur in well-regulated observing.

Mr. HAYFORD'S conclusions are all borne out by the experience of the German observers. They have found the relative personal equations reduced to one tenth of their former value, and so small as to be masked, if existing at all, by the minute outstanding accidental error. ALBRECHT found that the mean error of a single night's determination of longitude was reduced from values between $\pm 0^s.043$ and $\pm 0^s.064$ to values between $\pm 0^s.020$ and $\pm 0^s.026$. Also, they have found their results singularly free from systematic errors of all kinds, and

that a moderate amount of practice suffices for making tolerably good observations.

The last section of Mr. HAYFORD'S publication is a review of the literature of the transit micrometer. To a professional reader this is the most important part; for, as already noted, Mr. HAYFORD'S work had a special purpose, while here he gives an excellent summary of a list of fifteen different publications—all but one by "those blessed Germans"—extending over the past sixteen years. The first published suggestion of this method came from Director CARL BRAUN, of Kalocsa, Hungary, in 1865. He attempted to construct a clockwork which should drive the movable thread, but was unsuccessful. This has been completely accomplished of recent years; but the observer's hand is required to maintain the finishing touch on the micrometer. Doubtless during the years following BRAUN'S first publication, there were many suggestions among astronomers to the same purpose; and the author records one definitely made by Mr. F. D. GRANGER, of the Coast Survey, in 1878.

Following closely upon the announcement by REPSOLD of the successful performance of his first transit micrometer, verifications of its superiority were presented in 1890 and 1891 by Dr. TH. ALBRECHT before the (European) International Geodetic Association and by Professor E. BECKER, who had applied the new micrometer to transits of the broken type. In a publication of the Prussian Geodetic Institute in 1901, ALBRECHT declared that the superiority of the new method was so complete that it should be employed in all primary longitude work. The experience of OERTEL and COHN in Germany and of the Washburn Observatory in this country with the new micrometer on meridian-circles—as transit instruments of the straight telescope type—demonstrated its superiority for the larger observatory instruments. And there would seem to be left no question of the desirability of the new micrometer for the present instruments of the U. S. Coast and Geodetic Survey. A. S. FLINT.

The Fifth Satellite of Jupiter.—Number 580 of the *Astronomical Journal* contains an article by Professor E. E. BARNARD, giving a long series of observations of the fifth satellite

of *Jupiter,* made with the large refractor of the Yerkes Observatory during the years 1903 and 1904. These measures, as well as previous ones by the same observer, were made by measuring with a micrometer the distance of the satellite from the limb of *Jupiter,* and then applying a reduction factor for the semi-diameter of the planet. The values of the reduction factor were taken from a table previously constructed by Professor BARNARD from an elaborate series of observations of the apparent diameter of *Jupiter.* A few measures were made by determining distance and position-angle of the fifth satellite with respect to one of the brighter satellites. The two methods are quite different, and each has its advantages and each its disadvantages.

There is a third method of determining the position of a satellite which seems not to be used by observers of these objects. Why should not the position of a satellite be determined in the same way that the position of a comet or an asteroid is determined,—namely, by measuring its position on the sky with respect to a star or stars of known coordinates? Such observations can be made as accurately, and in most cases more accurately, than by either of the two methods usually employed; and it would seem, theoretically at least, to be a decided advantage to the computer who handles the observations to have the position of the satellite referred to fixed points rather than to constantly moving points. The object of all observations of position of satellites is to obtain material from which to compute the orbit of the body, and this can be done as easily, or more easily, from accurate right ascensions and declinations of the body than from the observations ordinarily made.

This question is worth looking into, and I hope at no very distant date to examine it more critically in order to determine just what observations should be made upon a satellite in order to compute the elements of its orbit with the greatest possible accuracy and facility. It may be that a combination of the observations mentioned should be made. S. D. T.

Figure of the Sun.—In number 104 of these *Publications* attention was called to an article by Dr. C. L. POOR on the variable figure of the Sun. In the *Astrophysical Journal* for

December Dr. POOR has contributed a second article on the same subject. This second article deals with the results obtained from an elaborate series of observations upon the diameter of the Sun made by Messrs. SCHUR and AMBRONN, with a six-inch Repsold heliometer of the Göttingen Observatory. These observations extend over a whole sun-spot period, from 1890 to 1902.

Dr. POOR finds in these observations further confirmation of the deductions obtained from his previous investigations,—namely, that the equatorial diameter of the Sun increases, with respect to the polar diameter, at the same time that the number of spots increases, and *vice versa*. The amount of the variation in the ratio between the equatorial and the polar diameters, however, is not so great in the observations of SCHUR and AMBRONN as was obtained from the Rutherford photographs.

The *Astronomische Jahresbericht*, prepared hitherto by the late Professor WISLICENUS, will now be undertaken by Professor BERBERICH, of the Recheninstitut in Berlin.

The following notes have been taken from recent numbers of *Science*:—

The Paris Academy of Sciences has awarded the Lalande prize to Professor WILLIAM HENRY PICKERING, of Harvard University, for his discovery of the ninth and tenth satellites of *Saturn*.

At the New York meeting of the Astronomical and Astrophysical Society of America, on December 28-30, 1905, the following officers were elected for the ensuing year: President, E. C. PICKERING; First Vice-President, G. E. HALE; Second Vice-President, W. W. CAMPBELL; Secretary, G. C. COMSTOCK; Treasurer, C. L. DOOLITTLE; Councilors, E. B. FROST and HAROLD JACOBY. Councilors ORMOND STONE and W. S. EICHELBERGER hold over from the preceding year. The time and place of the next meeting will be determined by the Council.

The will of the late CHARLES T. YERKES, who owed his large fortune to the direct application of recent advances in science, makes provision for three important institutions, which are to bear his name. The Yerkes Observatory, to

which he has already contributed liberally, receives one hundred thousand dollars; the Yerkes Galleries and the Yerkes Hospital are to be established in New York City on the death of his widow, or sooner, should she wish.

The Late Astronomer Royal of Ireland.—Mr. CHARLES J. JOLY died at Dunsink Observatory, Dublin, on the 4th of January last. He was educated at Galway, and in 1882 entered Dublin University, where he had an academic career of the highest distinction. In 1886 he took the mathematical studentship and first place in science among the men of his year. Eight years later he was elected a Fellow of Trinity College, and identified himself closely witn the advanced scientific teaching of that institution. In 1897 he succeeded Mr. A. RAMBAUT as the Astronomer Royal of Ireland. This post is attached to the Andrews Professorship of Astronomy, which was founded at Dublin University in 1783. The tenant of both offices resides at Dunsink Observatory, which is five miles outside Dublin, and is used both for independent observation and as the university school for the teaching of astronomy. Mr. JOLY was efficient both as a student and as a teacher of that science, and he maintained the high reputation of his chair, which has given to England in the past Sir ROBERT BALL, Mr. RAMBAUT, and other eminent scientists. He was a member of the Royal Society and of other learned associations. He was forty-one years of age.—*Extract from the Times.*

New Astronomer Royal for Scotland.—Mr. F. W. DYSON, F. R. S., Chief Assistant, Royal Observatory, Greenwich, has been appointed Astronomer Royal for Scotland, and also Professor of Practical Astronomy, Edinburgh University. Mr. DYSON studied at Cambridge, and was second wrangler and Smith's prizeman in 1889, and also Isaac Newton student. He is Secretary of the Royal Astronomical Society, and has published contributions on mathematical and astronomical subjects.—*Extract from the Times.*

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE STUDENTS' OBSERVATORY, BERKELEY, JANUARY 27, 1906, AT 10 P. M.

President TOWNLEY presided. A quorum was present. The minutes of the last meeting were approved

ELECTION.

Miss MARY G. MCCOMAS, 1001 Leavenworth Street, S. F., Cal., was elected to membership.

It was, upon motion,

Resolved, That No. 106 of the *Publications* be printed in an edition of 1250 copies.

Resolved, That the Astrophysical Observatory and the Astronomical Observatory, both of Heidelberg, Germany, be placed upon the list of corresponding institutions.

WILLIAM ALVORD FUND.

The Treasurer reported that the $5,000 bequeathed to the Society by the late Mr. ALVORD were received on December 20, 1905, and that, by order of the Finance Committee, the money was placed on deposit with the following savings banks:—

$2,500 with the Humboldt Savings and Loan Society,
$2,500 " " Savings and Loan Society.

The following resolutions were adopted:—

Resolved, That the bequest to the Society, by the late Mr. WILLIAM ALVORD, of $5,000 be placed in a separate fund, to be known as the WILLIAM ALVORD FUND of the Astronomical Society of the Pacific; and

Resolved, That the income from the William Alvord Fund be devoted to specific purposes; and that it shall become available only through a resolution duly adopted at a regular or special meeting of the Board of Directors; provided, however, that the income for the fiscal year 1906–1907 be devoted to the *Publications* of the Society, and that an acknowledgment to the Alvord Fund be printed in the *Publications*.

Resolved, That the Finance Committee be empowered to invest the funds of the William Alvord Fund, upon the consent of the President, in such first-class bonds as they may deem advisable.

The proposed amendment to Article IX of the By-Laws was referred back to the Committee for further consideration.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE STUDENTS' OBSERVATORY, BERKELEY, JANUARY 27, 1906, AT 8 P. M.

The meeting was called to order by President TOWNLEY.

The following papers were presented :—

Lecture by Mrs. ISAAC ROBERTS: "An Astronomer of Bygone Days and an Astronomer of Our Own Time."

The Lick Observatory-Crocker Eclipse Expedition to Spain, by Prof. W. W. CAMPBELL and C. D. PERRINE.

The Lick Observatory-Crocker Eclipse Expedition to Egypt, by Prof. W. J. HUSSEY.

Shadow-Bands at Total Solar Eclipses, by M. ROSO DE LUNA.

Variable Star Notes, by Miss ROSE O'HALLORAN.

Planetary Phenomena for March and April, 1906, by Prof. M. MCNEILL.

The Chairman then introduced the lecturer of the evening, Mrs. ISAAC ROBERTS, who read her paper on "An Astronomer of Bygone Days (TYCHO BRAHE) and an Astronomer of Our Own Time (ISAAC ROBERTS)," and showed a number of stellar photographs taken at the Starfield Observatory.

A committee to nominate a list of eleven Directors and Committee on Publication, to be voted for at the annual meeting, to be held on March 31st, was appointed as follows: Messrs. O. VON GELDERN (Chairman), R. T. CRAWFORD, J. D. GALLOWAY, J. K. MOFFITT, C. D. PERRINE.

A committee to audit the accounts of the Treasurer, and to report at the annual meeting in March, was appointed as follows: Messrs. C. S. CUSHING (Chairman), A. H. BABCOCK, FREMONT MORSE.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. S. D. TOWNLEY . . . . . *President*
Mr. A. O. LEUSCHNER . . . . . *First Vice-President*
Mr. CHAS. S. CUSHING . . . . . *Second Vice-President*
Mr. A. H. BABCOCK . . . . . *Third Vice-President*
Mr. R. G. AITKEN, Mr. F. R. ZIEL . . . . . *Secretaries*
Mr. F. R. ZIEL . . . . . *Treasurer*

Board of Directors—Messrs AITKEN, BABCOCK, BURCKHALTER, CAMPBELL, CROCKER, CUSHING, HALE, LEUSCHNER, PARDEE, TOWNLEY, ZIEL.
Finance Committee—Messrs. CUSHING, LEUSCHNER, WM. H. CROCKER.
Committee on Publication—Messrs AITKEN, TOWNLEY, NEWKIRK.
Library Committee—Mr. CRAWFORD, Miss O'HALLORAN, Miss HOBE.
Committee on the Comet-Medal—Messrs. CAMPBELL (*ex-officio*), BURCKHALTER, CROCKER.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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HERMANN CARL VOGEL

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ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO GEHEIMER OBER-REG. RATH PROFESSOR DR. HERMANN CARL VOGEL.

BY SIDNEY D. TOWNLEY.

At the close of another fiscal year in the history of the Astronomical Society of the Pacific it becomes my pleasant duty, as your retiring President, to review briefly the past progress of the Society and to make public announcement of the sixth award of the Bruce Gold Medal.

This Society was founded February 7, 1889, as the result of the co-operation between amateur and professional astronomers in observing the total solar eclipse on New Year's day of that year. The Society was designed to be popular in the best sense of the word, and its progress for several years was very rapid. Later, however, a slight retrograde movement set in, but, as in the case of the planets, this did not last long, and we are happy to state that the Society is again moving with forward motion. The membership, though not large, is of a solid, permanent character, and the *Publications* of the Society now hold a recognized place in astronomical literature. Seventeen volumes of the *Publications* are now complete, and the Society's library contains fourteen hundred books and about the same number of pamphlets. Through the liberality of generous friends the Society now possesses an endowment fund, including the Life Membership Fund, of nearly $17,000, the interest from which is used for various purposes,—such as the bestowal of the Bruce Gold Medals, of the Donohoe Comet-Medals, for additions to the library, etc.

In 1897, the late CATHERINE WOLFE BRUCE, of New York, gave to the Society a fund of $2,750, of which $250 was to

be used for the purchase of a gold medal to be awarded, regardless of race or sex, for distinguished services to astronomy. The remaining $2,500 was to be invested, and the interest therefrom used for the bestowal of other medals, not oftener than once a year. The directors of six of the largest and most prominent observatories in the world—Berlin, Harvard, Greenwich, Lick, Paris, and Yerkes—are each asked to nominate three astronomers as worthy to receive the medal, and from the persons thus nominated the medalist is chosen by the directors of the Society.

The first award of the medal was made to the eminent American astronomer, Professor SIMON NEWCOMB; the second award to one of Germany's distinguished sons, Professor ARTHUR AUWERS; the third award to an Englishman who attained eminence far away from his native isle, Sir DAVID GILL, Director of the Cape of Good Hope Observatory; the fourth award to Professor GIOVANNI VIRGINIO SCHIAPARELLI, Director of the Observatory at Milan, and Italy's most renowned astronomer; the fifth award to Sir WILLIAM HUGGINS, another of England's famous astronomers, who is still busily engaged in scientific researches at the age of eighty-two; and now it gives me great pleasure to publicly announce that the sixth award of the medal has been made to another of the eminent sons of Germany, Professor HERMANN CARL VOGEL, Director des Astrophysikalischen Observatorium zu Potsdam.

Professor VOGEL has been connected with the Astrophysical Observatory at Potsdam ever since it was established in 1874, and his work has therefore been almost entirely along the line of the new astronomy, or astrophysics. He now stands with our fifth medalist, Sir WILLIAM HUGGINS, as one of the pioneer workers in this highly interesting branch of astronomy, and his many published writings, only a portion of which are to be found in the volumes of the Astrophysical Observatory, will stand as a lasting monument to his industry, ability, and constant devotion to the queen of all the sciences, astronomy.

Our medalist was born in Leipsic March 4, 1842. His education was obtained at the University of Leipsic, and he became assistant in the Leipsic Observatory in 1864. From 1870 to 1874 Doctor VOGEL was director of Herr von BULOW'S private observatory at Bothkamp, near Kiel. From 1874 to

1882 he was associated with the commission which had in charge the building of the Astrophysical Observatory at Potsdam, and in the latter year, when this magnificent institution was turned over to the Government by the commission, Doctor VOGEL became its first director, and still remains in that position.

The observatory at Potsdam was built and is maintained by the Prussian Government. It was at first indirectly connected with the University Observatory at Berlin, but it now has no connection with any educational institution, although some of the astronomers of the observatory lecture at the University of Berlin.

The observatory is located on the summit of a hill, amid spacious, heavily wooded, and well-kept grounds, just outside of Potsdam, at a distance of about fifteen minutes' walk from the railway station. The general construction of the observatory may be seen from the illustration presented herewith.[1] The principal instruments of the original observatory are three refractors,—one of 30 centimeters (12 inches) aperture, objective by SCHROEDER, mounting by REPSOLD, in the central dome; one of 21 centimeters (8 inches) by GRUBB, in the western dome, used chiefly for the observation of sun-spots; and a 13-centimeter (5 inches) telescope by STEINHEIL, in the eastern dome, used for spectroscopic observations of the Sun and for photometric work. It should be stated that the Potsdam Observatory was intended originally for solar work, and it was indeed formerly called the Sonnenwarte, or solar observatory, as distinguished from a Sternwarte, or star observatory. One of the rooms of the observatory contains a very large and accurately constructed spectrometer, by BAMBERG, which is used for study of the solar spectrum, the rays of light from the Sun being brought to the collimator in a horizontal direction by means of a heliostat. The rooms of the observatory contain many smaller instruments and pieces of apparatus.

In 1889 it was decided by an international conference which met in Paris to take up, by co-operation among a num-

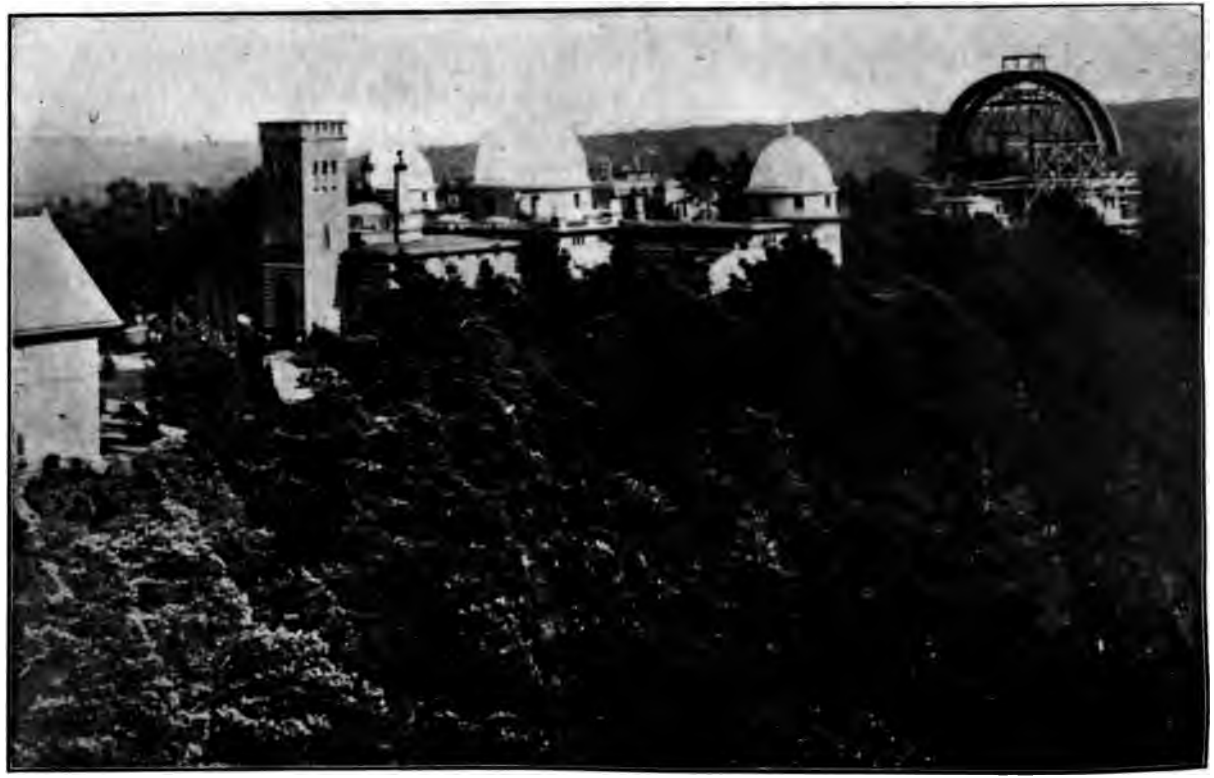
[1] The photographs from which this cut and the one of Doctor VOGEL were made were kindly loaned by Prof. LEUSCHNER. Another view of the observatory and a short descriptive article by Prof. LEUSCHNER may be found in Volume IV of these Publications.

ber of observatories, the almost herculean task of photographing the entire sky and making catalogues and charts of the stars contained upon the plates obtained. The Potsdam Observatory engaged to take part in this work, and was assigned the zone lying between 31° and 40° of north declination. For this purpose a new photographic refractor of 45 centimeters (13 inches) aperture was provided and mounted in a dome detached from the main building. The instrument is in fact a doublet, a visual telescope of 23 centimeters (9 inches) being provided for the purpose of guiding the photographic telescope.

Again in 1900 a very material addition was made to the equipment of the observatory by the acquisition of a great refractor having a photographic objective of 80 centimeters (31.5 inches) and a focal length of 12 meters (39 feet), and also a visual telescope with aperture of 50 centimeters (20 inches) and focal length of 12½ meters (41 feet). This instrument is used chiefly for the determination of the velocities of stars in the line of sight, and is located in a dome situated on a second hill at some little distance from the main building. The unfinished dome may be seen in the illustration.[1]

Besides Director VOGEL there are a number of astronomers and assistants connected with the Potsdam Observatory, and an atmosphere of intense scientific activity prevails there. Fourteen well-filled quarto volumes have been issued in the regular series of publications of the Observatory. The investigations printed in these volumes cover a considerable range of problems in astrophysics. Among these may be mentioned observations of sun-spots, investigations of the solar spectrum, studies of the spectra of the planets and the fixed stars, photographic observations of the velocities of the stars, observations of variable stars, photometric determinations of stellar magnitudes, etc. In addition to the regular series of publications three volumes have been issued giving the results of the work undertaken in connection with the international plan to photograph the entire heavens, mention of which has already been made. These volumes contain the photographic magnitude and ap-

[1] An illustration showing the building after it was completed may be found in Volume XI (opposite page 215) of these Publications.



THE ASTROPHYSICAL OBSERVATORY, POTSDAM.

proximate position of 62,103 stars all lying in the zone 31° to 40° north declination. This work is not yet completed.

All of this work has been done under Professor VOGEL's direction, and we can easily imagine that the administrative duties of such a large institution might fully absorb all of the energy of the director. Such, however, has not been the case, for Professor VOGEL has found time to carry on scientific work, and has, altogether, published a large number of papers and memoirs on astronomical subjects. They have been printed mostly in the volumes of the Potsdam Observatory, in the *Sitzungsberichte* of the Berlin Academy of Sciences, in the *Astronomische Nachrichten*, and in the *Astrophysical Journal*. While looking up Doctor VOGEL's writings I very soon became convinced that it would be quite out of the question for me, except by the expenditure of an amount of time impossible for me to give to the matter at present, to present to you anything more than a mere outline of his scientific activity. Fully half of the one hundred volumes of the *Astronomische Nachrichten* which have been issued since 1866 contain one or more articles by Doctor VOGEL.

The *Astronomische Nachrichten* (volume 67) contains an article by Doctor BRUHNS, Director of the Leipsic Observatory under date of July 1, 1866, in which are given some observations by Herr VOGEL, and they constitute probably the first scientific observations made by our medalist. These consist of observations of minor planets, observations of a group of sun-spots, with drawings, and an account of some experiments made in photographing the Sun. It is seen that at this early date Doctor VOGEL was interested in solar observation and in photography, and it should be remembered that photography was at that time in its infancy. While at Bothkamp (1870 to 1874) Doctor VOGEL took up solar and spectroscopic work, and it was there, at a private observatory, that the first astrophysical work was done in Germany.

Although provided with only an 11½-inch refractor, a mere infant in comparison with the giant telescopes of the present day, yet the four years spent by Doctor VOGEL at the Bothkamp Observatory were very prolific ones, and some of the most notable of the spectroscopic work was done during that

time. The spectra of all classes of heavenly bodies were examined, but the most notable result of Doctor VOGEL'S activity during this period is perhaps his observations of the spectra of the planets. The Copenhagen Academy of Sciences offered a prize for the best memoir on the spectra of the planets, and it was our medalist to whom this prize was awarded in 1874. Although these investigations were made over thirty years ago, and with a telescope of only 11½ inches aperture, still many of them have never been surpassed, and Doctor VOGEL'S work is still quoted as authority on the spectra of the planets.

It was during this period also that he proposed a new classification of stellar spectra, which is, perhaps, more strictly speaking, a modification of SECCHI'S classification. This is a very important subject, but time will not permit me to take up a detailed consideration of it. It is perhaps sufficient to state that although more elaborate systems of classification have been proposed, still the general classification laid down on broad lines by SECCHI and by VOGEL is still sufficient for most purposes.

The great activity of Doctor VOGEL at Bothkamp and the brilliant success attained there led to his selection as chief observer and afterwards director of the Astrophysical Observatory at Potsdam.

Among the many brilliant achievements of our medalist there is none perhaps which stands out more prominently than his observations of the velocities of the fixed stars in the line of sight. The principles underlying this method were explained to the members of this Society in a lecture by Professor CAMPBELL not very long ago, and as they have been explained frequently in astronomical journals it seems hardly necessary for me to repeat them here. It was in 1868 that Doctor HUGGINS first announced the method of determining velocities in the line of sight by measuring the displacement of the lines of the spectrum. This work was taken up by Doctor VOGEL while at the Bothkamp Observatory, and the radial velocities of some of the brighter stars, *Sirius*, *Procyon*, *Capella*, *Altair*, and *Vega*, were measured by visual methods, but it was not until Doctor VOGEL had at his disposal the finer equipment of the Potsdam Observatory that any great progress was made.

About the year 1887 he commenced experiments in photographing stellar spectra. By measuring the displacement of the lines, referred to a comparison spectrum on the same plate, it was found possible to determine these displacements to a much greater degree of accuracy than by visual methods, and also to measure the spectra of stars which, on account of their faintness, could not be reached by visual methods. In 1892 the results of this very important work were given to the world in part I of volume VII of the *Publications* of the Astrophysical Observatory. The velocity in the line of sight of fifty-one of the brightest stars of the sky was measured, and it was indeed a notable achievement. Since that time the work has been taken up at a number of places,—Pulkova, Meudon, Greenwich, Emerson McMillin, Yerkes, Lowell, and Lick observatories. The success of the Lick Observatory in this field of work is well known to members of this Society and need not be dwelt upon at this time. Many improvements have been made in the instrumental equipment with which this problem has been attacked, and a degree of refinement in the results has now been attained which probably far surpasses the wildest dreams of the originators of the method.

Several by-products have been obtained in the prosecution of this work, the most notable of which is the discovery of an entirely new species of double stars, the so-called spectroscopic binaries, dual systems in which one of the components, either on account of the relative faintness of its light or its proximity to a brighter star, or both, is invisible. This is an excellent example of the versatility of modern science, and it is indeed a notable achievement that astronomers should now possess methods of research that are capable of disclosing to us the existence of bodies situated at the confines of the universe and forever invisible in the most powerful telescopes. Our medalist shares with Professor PICKERING the honor of being the first to prove and announce the existence of such systems as these. It was in 1889 that Professor VOGEL announced that β *Persei* (*Algol*) and α *Virginis* (*Spica*) had invisible companions, which revolved with the bright stars around common centers of gravity; it was during the same year, and in fact shortly before Doctor VOGEL'S announcement, that

Professor PICKERING announced that ζ *Ursae Majoris* (*Mizar*) and β *Aurigae* are attended by invisible companions, and thus it happened, as has been the case many times before, that an important discovery was announced almost simultaneously by two men working entirely independently of each other.

The discovery that *Algol* is attended by an invisible companion possessed a double interest from the fact that this discovery afforded an explanation of the peculiar type of variability exhibited by this star, and indeed confirmed an explanation, offered many years before, but based upon purely hypothetical considerations. The history of this star *Algol* has been written many times, but as the story is a very interesting one it will perhaps bear one more repetition. I shall, however, confine myself to a bare statement of the facts, without attempting to adorn my story with any of those embellishments that it would be a comparatively simple matter to provide. *Algol* at its normal brightness shines with almost the same amount of light as the Pole Star. That the brightness of *Algol* is at times considerably less than that of *Polaris* was first noticed by MONTANARI in 1669, but it was not until over a century later (1783) that GOODRICH discovered the exact nature of the variations of *Algol's* light and suggested an explanation. *Algol* remains at the same brightness most of the time, but at regular times of a little less than three days the light of the star begins to decrease and continues to decrease for about five hours, reducing the magnitude of the star from 2.2 to 3.7. The light then begins to increase again, and at the end of another five hours the normal brightness has been regained. Now, GOODRICH suggested that this diminution which takes place in the light of *Algol* might be caused by the interposition of a dark companion revolving around the star in a plane passing through our Sun, and therefore the bright star becomes partially eclipsed at regular intervals when the dark companion passes between *Algol* and the Earth. It follows, of course, that if such a dual system actually exists, the dark companion not only revolves around the bright star, but, conversely, the bright star revolves around the dark one, or, more correctly speaking, the two revolve around a common center of gravity, situated somewhere on the line joining their centers, midway

between centers if the masses of the bodies are equal, but nearer the heavier one if the masses are unequal. It is therefore evident that *Algol* is revolving in an orbit, probably nearly circular, and, if the plane of this orbit passes through the Earth, then at one part of it *Algol* must be moving toward the Earth, half a period later moving away from the Earth, and at two other points will be moving in a direction perpendicular to the line joining *Algol* and the Earth. If this theory be correct, then it should be possible to detect, by means of the spectrograph, this change in the motion of *Algol* toward and from the Earth. Doctor VOGEL was the first person to undertake a solution of the problem, and his observations resulted in a complete verification of the theory. Before each minimum *Algol* was found to be moving away from the Sun at the rate of 42 kilometers (26 English miles) per second, and after each minimum to be approaching with an equal speed, while at intermediate times the imprinted lines showed no displacement, and hence the star was moving perpendicularly to the line joining *Algol* and the solar system. From these data, the known period of the variable, and the amount of obscuration caused by the passage of the dark companion, Doctor VOGEL was able to compute, on the assumption that the two bodies were of equal densities, the following results for this interesting variable spectroscopic binary:—

	Kilometers.		Miles.
Diameter of *Algol*	1,700,000	=	1,061,000
Diameter of the satellite.....	1,330,000	=	830,000
Distance between their centers...	5,180,000	=	3,230,000
Orbital velocity of *Algol*.....	42	=	26
Orbital velocity of the satellite....	89	=	55

Masses of the two bodies..four ninths and two ninths of the Sun's mass.

Doctor VOGEL has given much time to the study of the Sun, and the maps of the solar spectrum given in volume I of the *Publications* of the Astrophysical Observatory are perhaps the finest maps of the solar spectrum ever printed, and are almost universally used for purposes of instruction and illustration. Our medalist has given particular attention to the study of the spectra of new stars, and his memoirs on *Nova Aurigae* and *Nova Persei* occupy conspicuous places in the literature referring to these remarkable bodies. He has also

studied the spectra of nebulæ, clusters, the Wolf-Rayet stars, comets, the aurora, the zodiacal light, lightning; in fact, there is, I believe, no class of celestial bodies or celestial light phenomena that has not been studied by this indefatigable worker.

Doctor VOGEL has devised many pieces of apparatus and improvements to spectroscopes. The observations made by him possess a high degree of precision, and many of the results obtained by him with small telescopes, in a rather poor climate from an astronomical standpoint, have not been surpassed by observers in possession of much more powerful instruments of research. I think it may truthfully be said that Professor VOGEL has always obtained from his instruments the utmost that they were capable of yielding to him.

Many honors have been conferred upon Professor VOGEL, but I have been unable to obtain a list of these. The gold medal of the Royal Astronomical Society was conferred upon him in 1893 for his "spectroscopic and other astronomical observations." Professor VOGEL's published writings show him to be not only a keen observer, but also a man of rare judgment. His activity has led him into nearly every field of astronomical spectroscopy, not in a haphazard way, for we recognize in perusing his writings, that they are the products of a master mind.

I trust that this short, and I fear very inadequate, outline of the scientific activity of our medalist has been sufficient to show you the wisdom of your Board of Directors in selecting Professor VOGEL, for this signal honor, from the list of eminent astronomers sent by the directors of the nominating observatories.

As San Francisco is far removed from the older centers of scientific activity, we have not yet been fortunate enough to have one of the Bruce Medalists with us. In the absence of Doctor VOGEL, I hand to you, Mr. Secretary, this medal, a mark of the highest distinction that it is possible for this Society to bestow upon any astronomer, for transmission to the person whose name has been engraved upon it. You will kindly send with it the greetings of the members of the Astronomical Society of the Pacific, and especially of its Board of Directors, and our earnest wish that his life may be spared for many years in order that he may enjoy in the evening of life the well-earned fruits of great scientific activity.

March 31, 1906.

THE NEBULAR HYPOTHESIS.[1]

By R. G. Aitken.

....The general consensus of opinion for more than a century has been that our Sun and its system developed into its present form from an earlier nebular state. In fact, the harmonious relations, independent of gravitation, that are actually observed in the planetary system point incontrovertibly to a common origin, and that this primitive form was a nebula is postulated by all theories. Even the meteoritic hypothesis, with which Lockyer's name is identified, does not contradict this assumption, for the aggregation of meteorites from which he derives the system must, dynamically at least, be identical with a nebula, as Darwin has proved. The various theories differ, however, quite radically as to the primitive form and physical conditions of the nebula and as to the processes of development into the present planetary system.

Our immediate concern is with the specific theory advanced by Laplace in 1796, and in more elaborate form in 1808,—a theory that has been characterized as "perhaps the most beautiful and fascinating and one of the boldest speculations ever offered in any science," and one that has profoundly influenced the progress of thought in the nineteenth century.

Laplace assumed a nebula of intensely heated gas which by the influence of gravitation had become approximately spheroidal in form and rotated slowly upon an axis practically like a solid body,—the outer portion, that is, moving more rapidly than the inner parts. This nebula, extending far beyond the orbit of the outermost planet and subject practically to the action of no external forces, gradually contracted by its own gravitation, the angular rotatory velocity necessar-

[1] This article is a portion of a lecture delivered before the class in modern astronomy at the University of California on March 17, 1906. It is here printed because it contains a brief resume of recent important articles by Professors Chamberlin and Moulton questioning the validity of the Laplacian theory of planetary evolution, and outlining a substitute based upon the assumption of an original spiral nebula. These articles are:

"An Attempt to Test the Nebular Hypothesis by an Appeal to the Laws of Dynamics," by F. R. Moulton, "Astrophysical Journal," Volume XI, p. 103, 1900.

"On the Possible Function of Disruptive Approach in the Formation of Meteorites, Comets, and Nebulae," by T. C. Chamberlin, "Astrophysical Journal," Vol. XII, p. 17, 1900.

"Fundamental Problems of Geology," by T. C. Chamberlin, Year Books, Nos. 2, 3, and 4, Carnegie Institution of Washington, 1903, 1904, 1905.

"On the Evolution of the Solar System," by F. R. Moulton, "Astrophysical Journal," Vol. XXII, p. 165, 1905.

Also articles by Professor Chamberlin in the "Journal of Geology."

ily increasing and the polar diameter diminishing as it contracted, until the centrifugal forces at its boundary balanced the attraction of the central mass. Then an equatorial ring was abandoned, the rest of the matter continuing to contract. By successive repetitions of this process other rings were left behind, and these rings, being in general in unstable equilibrium, could not maintain themselves as rings, but, slowly collecting, eventually formed the nearly spherical masses of the planets. These in turn, or at least some of them, by similar processes abandoned rings, which in time became satellites.

In this specific form the theory commanded immediate and almost universal acceptance. Difficulties indeed it encountered at once, and in course of time various modifications were suggested, and more or less approved, to account for the observed facts that were inconsistent with LAPLACE'S formulation. For example, the retrograde motion of the satellites of *Uranus* and *Neptune* and the rapid motion of the inner satellite of *Mars* were anomalies that demanded explanation. Again, it was evident, when the mechanical equivalent of heat was discovered and the principle of the conservation of energy established, that the high initial temperature assumed by LAPLACE was not essential. The potential energy of the separated particles of the nebula would afford a sufficient explanation of the present temperature of the Sun.

But though beset by difficulties and subject to modification in various details, the hypothesis in its essential features held its place throughout the century. It was accepted by men like HELMHOLTZ, KELVIN, NEWCOMB, and DARWIN, and was taken as the basis of all the calculations that have so far been made as to the age of the Sun, the amount of the Sun's heat and radiation, and the probable duration of the system in its present form, calculations obviously of the most fundamental importance in geology as well as astronomy.

The critics of the theory, however, gradually multiplied and brought forward ever stronger facts and arguments for its overthrow. More than forty years ago M. BABINET showed that when the nebula filled the orbit of *Neptune* more than 27,000 centuries would have been needed for a single revolution, and that even when the central mass had contracted to

the size of the Earth's orbit it must still have taken 3,181 years. With such slow motion the centrifugal forces would never have overbalanced the central attraction and no rings could have been abandoned.

A few years later (1864) KIRKWOOD showed, from the extreme tenuity of the original mass, that it could have possessed no power of resistance to the slightest strain. Hence the surface of the nebula would have been in continual process of disintegration,—that is, matter would have been abandoned by the nebula continuously and not in rings occasionally.

Of late years the development of the kinetic theory of gases has been the source of fresh arguments against LAPLACE'S hypothesis.

Perhaps the strongest summary of all the objections to the theory that have so far appeared is to be found in the papers of Professors CHAMBERLIN and MOULTON in recent numbers of the *Astrophysical Journal*, the *Journal of Geology*, and the year-books of the Carnegie Institution.

Doubts first arose in the minds of these investigators as to whether the attractive force of the Earth-Moon nebular ring would be sufficient to prevent the lighter gases, such as hydrogen and helium, from escaping into outer space. Reasoning from the kinetic theory of gases and the molecular velocities established by experiment, they concluded that it was very doubtful whether any matter, even that having the lowest molecular activity, could have been retained by such a ring. They were then led to examine the whole theory critically and to test its various assumptions by an appeal to known mechanical laws.

To give the theory every benefit in this investigation, the special assumptions of LAPLACE as to temperature and physical condition of the original nebula were disregarded and the theory taken only in its broadest outlines,—namely, that the matter now in the solar system was once in a gaseous or meteoroidal state and then filled *Neptune's* orbit and formed a spheroidal-shaped mass. If the matter was in the gaseous state, the only further condition imposed is that it was in hydrodynamic equilibrium, rotating practically as a solid with an angular velocity equal to that of our planet *Neptune*. If

the matter was meteoroidal in its condition, then it is assumed that the assemblage of meteoroids behaved sensibly like a mass of gas, an assumption that DARWIN has shown to be valid. In either case the primitive mass was a spheroidal nebula. This nebula was not subject to the action of any external forces, but contracted under its own gravitation, and as it did so it either left off successive rings or divided by some fission process, and the detached masses collected and formed planets and satellites.

Even in these broad outlines, Messrs. CHAMBERLIN and MOULTON find it impossible to uphold the theory. The objections they raise to it are classed in three categories: I. Comparison of observed phenomena with those which would result from the expressed or implied conditions maintained by the hypothesis; II. Answers to the question whether the supposed initial conditions could have developed into the existing system; III. Comparison of those properties of the supposed initial system with the one now existing which are invariant under all changes resulting from the action of internal forces.

Into the first category fall such anomalies as the high inclination of the orbits of *Uranus* and *Neptune*, which have been already mentioned, and the fact that *Mercury* departs more from the average inclination of the planetary system than any other planet, whereas by the theory the planes of the planets' orbits ought to be more nearly coincident as we approach the Sun.

The rapid revolution of *Phobos* relatively to the rotation time of *Mars*, which has been noted above, is also brought forward under this head. This anomaly was ingeniously accounted for by G. H. DARWIN, who reasoned that as the solar tidal friction would serve to retard the planet's rotation without affecting the satellite's orbital motion, it might well be that the revolution period of *Phobos* represented the rotation time of *Mars* at the time the *Phobos* ring of matter was abandoned by the planet. Accepting this explanation, Dr. MOULTON shows that a still more serious difficulty of the same kind is found in the motion of the inner ring of *Saturn*, for this ring revolves nearly twice as fast as the planet rotates, and at *Saturn's* distance from the Sun the solar tides are so feeble

and ineffective that it would require several thousand times as many years to produce the present relation between the two motions in the Saturnian system as that between the motions of *Mars* and *Phobos*.

Another strong objection falling into this category is founded upon the distribution of mass in the solar system. On the assumption of anything like homogeneity in the original nebular mass, the densities of the successive planetary rings ought to be approximately the same, or, if the primitive nebula grew denser towards its center under the pressure of its own gravitation only, the planetary rings ought to increase in density with a certain degree of regularity as we approach the Sun. Assuming that each planet was formed from a ring extending halfway to the two adjacent planets, we can calculate the density of these rings. Making this calculation, and taking the density of the Earth-Moon ring as unity, we find:—

Mercury.....	0.015	Jupiter	0.609
Venus.....	1.010	Saturn	0.028
Earth.....	1.000	Uranus	0.0012
Mars.....	0.003	Neptune	0.0008

This argues a degree of heterogeneity in the original nebula that seems decidedly at variance with the conditions assumed by the Laplacian hypothesis.

The first two arguments advanced in the second category we have already touched upon,—namely, first, that on the kinetic theory of gases the lighter gases would in all probability have escaped from the original nebula, and all the atmospheric gases and water-vapor would certainly have been lost by the Earth-Moon ring, for its gravitative control would have been far less than that of the Moon at present, and this has practically neither water nor atmosphere; second, that in its original volume the solar nebula must have been so extremely tenuous (on assumptions that make the value too great, the density was found to be only 1-191,000,000,000 that of water) that its separate particles, under the conditions postulated by the theory, could have had no appreciable cohesion, especially at the surface, and that hence the matter would have been left behind continuously from the beginning of the process of contraction and no rings could have been formed. But assuming that the gases did not escape, and that rings were formed, could

the rings contract into planets? The answer is that they could not. It is shown that the probabilities of the union of even the largest bodies that could be supposed to exist in a planetary ring would be very slight indeed, and that even in the event that the greater part of the matter of a ring should be concentrated into a roughly spherical mass, the planet could not complete itself by gathering up the remaining matter of the ring.

The objections so far raised are serious enough, but when to them is added the one advanced in the third category the fundamental assumptions of LAPLACE'S hypothesis are seen to be invalid, and practically nothing is left of his theory except the very general conclusion that our present system originated in a nebula. This final argument is based on the theorem in mechanics which says that the moment of momentum of a system of particles undisturbed by external forces remains constant, no matter what changes may result within the system in consequence of the action of internal forces. By "moment of momentum" we mean the product of the masses of all the particles multiplied by their velocities and by their perpendicular distance from the axis of the system; and this product is always the same, no matter how the particles may rearrange themselves, provided the system is not disturbed by external forces.

It follows that the moment of momentum of the present solar system must be the same as that possessed by the original nebula. The present moment of momentum can be calculated with a high degree of accuracy. To calculate that of the original nebula, assume that it extended only to the orbit of *Neptune*, not beyond it, that it was spherical instead of spheroidal, and that its density followed the law developed by LANE, RITTER, HILL, DARWIN, Lord KELVIN, and others. These assumptions are all favorable to the Laplacian hypothesis; but when the calculations are made it is found that the moment of momentum of the original system must have been fully 213 times as great as that of the system as it exists at present. And, further, it appears that this ratio was not even constant during the process of solar evolution. For when the nebula had shrunk to *Jupiter's* orbit it was 140 to 1, when the

central mass was confined within the Earth's orbit the ratio was 1208 to 1, and at the Mercurial stage 754 to 1. Such variations preclude the possibility of systematic errors of computation, while the amount of the discrepancy cannot be accounted for by any error in the assumed law of density or by the approximations used to shorten the numerical process, but, in MOULTON'S words, "it points to a mode of development quite different from, and much more complicated than, that postulated in the nebular theory under discussion."

But if the Laplacian nebula is thus eliminated, what is to take its place as primal ancestor of our Sun?

An answer has been given to this question within the past few months, and while it is at present only advanced tentatively, it seems to meet the requirements so fully as to entitle it to a high degree of confidence.

The spectroscope has shown that the green nebulæ, which include those stellar and planetary forms which HERSCHEL thought to be next to the last stage of the genetic process by which irregular nebulæ become stars, and which afforded LAPLACE types of the primal solar nebula, consist largely of hydrogen, helium, and nebulium, with traces of a few other non-metallic elements, all in the gaseous, or free molecular state. No traces of metals are to be found in them.

The white nebulæ, on the other hand, give continuous spectra, and this is generally interpreted to mean that the luminous matter composing them is in the solid or liquid state, or gaseous under high pressure,—that the molecules, in other words, are in the aggregated state in distinction to the free state found in the green nebulæ. It is probable that the matter is in the solid state, but very finely divided, for the immense volume and the extreme tenuity seem conclusive arguments against the liquid form. What the chemical composition of these molecules is the spectroscope does not reveal to us.

Now, the white nebulæ include all the great spirals, and the work done by Professor KEELER with the Crossley reflector of the Lick Observatory proves that the nebulæ are not only far more numerous than had hitherto been supposed (Professor KEELER estimated the number at not less than 120,000) but that the typical nebular form is the spiral.

The significance of Professor KEELER's work cannot be better stated than in his own words. He says:—

"While I must leave to others an estimate of the importance of these conclusions, it seems to me that they have a very direct bearing on many, if not all, questions concerning the cosmogony. If, for example, the spiral is the form normally assumed by a contracting nebulous mass, the idea at once suggests itself that the solar system has been evolved from a spiral nebula, while the photographs show that the spiral nebula is not, as a rule, characterized by the simplicity attributed to the contracting mass in the nebular hypothesis."

This suggestion of Professor KEELER's has been taken up by Professors CHAMBERLIN and MOULTON, who have endeavored to develop an adequate theory of solar evolution from a spiral nebula.

The very appearance of such nebulæ is suggestive. Their most significant feature is the presence of two dominant arms arising from opposite sides of the central mass. They are disklike, and the matter contained in them is obviously very irregularly distributed, just as it is in our system. In fact, everything seems to indicate that they are governed by some system of combined kinetic energy and gravitation, which while exercising a general control of the whole, permits independence of its parts.

A spiral nebula, however, seems to show that it is not an original form, but that it was developed from some antecedent body. Naturally, we cannot go back from form to form in our search for the ultimate origin of matter; but it is interesting to note that a spiral nebula might have been formed from an antecedent sun by processes not unlikely to be realized among the stars. The collision of two suns, for example, is not impossible, and the passage of two suns within relatively small distances of each other is far from being an improbable event.

Now, our Sun, as we learn from observation, is the seat of violent activities. Prominences or protuberances are shot out thousands of miles above its surface with velocities sometimes as great as 300 miles per second. Only the enormous gravitative power residing in the Sun could balance the expansive potency of these elastic forces. But let another body—a larger sun—make a close approach to our Sun; then, on the principle of tidal forces, gravity would be relieved along the line of mutual attraction, and two exceptional protuberances

on opposite sides would arise, converting the Sun into a two-branched spiral. The two suns would swing about each other in sharp curves and the protuberances being differentially affected by the attraction of the companion sun would move in different curves, and thus rotatory motion would be initiated.

To account for our planetary system it is unnecessary to assume that the antecedent sun was entirely disrupted; it would be amply sufficient if under the influence of such a disruptive approach as that outlined only one or two per cent of its mass were dispersed in this manner, for the combined mass of the planets is only about one seven-hundredth that of the Sun.

But in the case of such a disruptive approach it is hardly possible that there would be only one outburst from the Sun. It is practically certain, on the contrary, that as the Sun was more and more affected by the differential attraction of its companion, and as the directions of attraction varied with the relative motion of the two bodies, there would be a succession of outbursts more or less pulsatory in character, resulting in two irregularly divided arms, along which the matter ejected would be distributed in larger or smaller knots connected by the more widely dispersed material. These knotty masses in turn would probably possess more or less rotatory motion, and the outer ones, being formed from the surface material of the Sun, would have a lower specific gravity than the inner ones which would originate from the lower depths.

"It is thus conceived [says Professor CHAMBERLIN] that a spiral nebula, having two dominant arms opposite one another, each knotty from irregular pulsations and rotatory, the knots probably also rotatory, and attended by subordinate knots and whirls, together with a general scattering of the larger part of the mass in irregular nebulous form, would arise from the simple event of a disruptive approach.

"The ejected matter at the outset must have been in the free molecular state, since, by the terms of the hypothesis, it arose from a gaseous body; but the vast dispersion and the enormous surface exposed to radiation doubtless quickly reduced the more refractory portions to the liquid and solid state, attended by some degree of aggregation into small accretions; hence the continuous spectrum which this class of nebulæ presents."

Of course, this is only one way out of many in which a spiral nebula might be formed, and the further elaboration of the theory does not all depend upon this particular genetic

history. It is sufficient to show that a spiral nebula might originate from a previously existing sun by a series of events not impossible and perhaps not unlikely to happen.

Assuming, then, a spiral nebula as our initial form, we note at once three conspicuous elements: (1) the central mass, obviously the future sun; (2) the knots on the arms, the nuclei of the planets; and (3) the diffuse matter, material for the growth of sun and planets. In the parent nebula of our own system the central mass must be assumed very great relatively, the knots to be irregular in size and placed at irregular distances from the center, and the mass of diffused matter to be very small compared to the central mass, but probably quite large as compared with the knots.

What will be the properties of a system formed from such a nebula? As developed by Dr. MOULTON, they are as follows:—

(1) The planets will all revolve in the same direction and in nearly the same plane;

(2) The sun will rotate in this same direction, and will have an equatorial acceleration;

(3) The more the planets grow the more nearly circular will their orbits become;

(4) The planets will rotate in a forward direction and nearly in the plane of the orbit;

(5) The more a planet grows, the more rapidly will it rotate;

(6) A planet may at first have many satellite nuclei, revolving in any direction, but the scattered material, acting as a retarding medium, will tend to drive all those nuclei not moving forward in the general plane of the system down upon their primary;

(7) The scattered material will develop and preserve circularity in satellite orbits having direct or forward motion of revolution, but will tend to make considerably eccentric the orbits of those in retrograde motion;

(8) A satellite may revolve more rapidly than its primary rotates;

(9) The system may have many planetoids (or asteroids) of interlocking orbits; the orbits of these bodies will be likely to present much greater deviations from the general plane of the system than those of the larger planets;

(10) The smaller planets will be cool and dense, the large ones hot and tenuous;

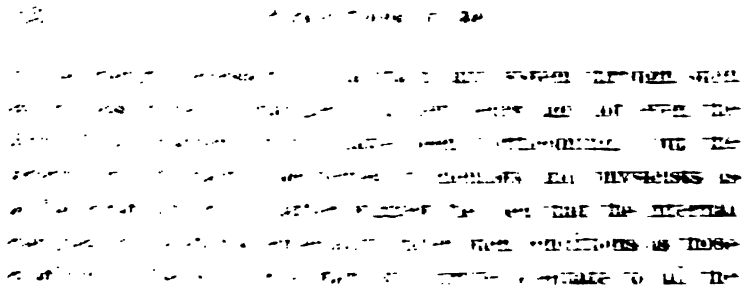
(11) The greater part of the mass will be found in the central Sun, but the greater part of the moment of momentum will belong to the planets.

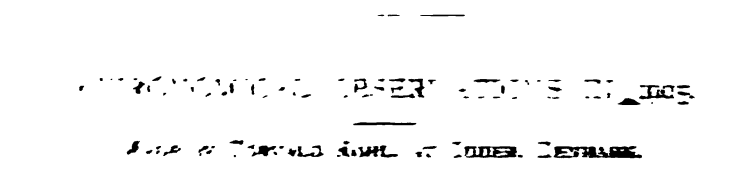
Clearly, if a system possessing these properties can be shown to follow necessarily from the assumed spiral nebula, or even if, by reasoning based on known mechanical and mathematical principles, it can be logically deduced from such an initial state, there can be no question about the standing of the theory. For it explains very nearly all the observed relations in the solar system and is contradicted by none.

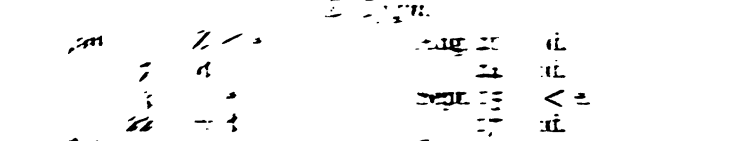
It would take us too far to follow the details of the arguments that have been presented in proof of the theory, but it must be said that they seem to be entitled to great weight. The propounders of the theory do not claim that they have as yet brought forward enough evidence fully to establish it; in fact, they distinctly state that they are devising further tests to apply to it and are investigating as fully as possible all the direct and indirect consequences likely to follow from the assumptions they have made. The evidence they present makes it already a good working hypothesis, for it explains as much as did the ring theory of LAPLACE, and also those phenomena that contradicted the latter, and nothing has yet been found to seriously question its validity.

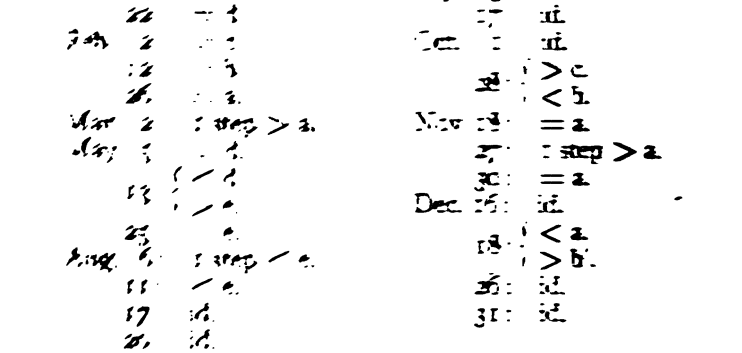
Professor CHAMBERLIN, who is more interested in the geological bearings of the theory, thinks it affords a rational explanation of the development of the Earth's atmosphere and hydrosphere and of the distribution of land and water, as well as of the phenomena of glaciation and vulcanism, of the carboniferous era, and of other difficult questions that beset the inquiries of geologists.

The most interesting contribution of the theory, however, is, as Professor MOULTON intimates, to the general philosophy of nature, for it shows important tendencies toward a dispersion of matter as well as toward its aggregation, and thus points to a cyclical character in the evolution of celestial bodies. The fundamental question that must be answered before we can fully accept the theory is, What is the source









S Ursæ Majoris.[2]

Jan.	1	$S = e$.	Feb.	2:	id.
	5	1 step $> d$.		12:	id.
	7	d.		26:	2 steps $< e$.
	10	2 steps $> d$.	Mar.	2:	id.
	12	d.		24:	1 step $> f'$.
	13	1 step $> d$.	Apr.	1:	$= f$.
	22	2 steps $> d$.		3:	$\begin{cases} < f. \\ > g. \end{cases}$
	31	$= d$.			

[1] *Vide* the sketch in the *Publications* A. S. P., No. 100, page 16.
[2] *Vide* the sketch in the *Publications* A. S. P., No. 73, page 56.

Apr. 8:	= g.
10:	id.
22:	id.
29:	invisible.
May 5:	very faint.
13:	invisible.
25:	< g.
June 8:	= f.
11:	> f. / < e.
July 8:	> e. / < d.
July 19:	= d.
28:	> d. / < c.
Aug. 11:	3 steps > d.
15:	id.
19:	id.
21:	1 step > d.
24:	3 steps > d.
Sept. 15:	2 steps > d.
17:	id.
21:	1 step > d.
30:	< d. / > e.
Oct. 9:	= e.
15:	2 steps < e.
19:	2 steps > f.
28:	= f.
Nov. 10:	< f. / > g.
18:	1 step < g.
24:	id.
27:	id.
30:	id.
Dec. 16:	invisible.
18:	id.
26:	= g.
31:	id.

T Ursæ Majoris.[1]

Jan. 1:	*T* < g.
7:	1 step < g.
10:	= f.
12:	> f. / < e.
13:	id.
22:	1 step > e.
31:	= c.
Feb. 2:	1 step > b.
12:	1 step > a.
26:	3 steps > a.
Mar. 2:	5 steps > a.
24:	2 steps > a.
Apr. 1:	= a.
3:	< a. / > b.
10:	id.
12:	< b. / > c.
22:	= c.
29:	= d.
May 5:	< d. / > e.
13:	< e. / > f.
25:	= g.
Aug. 11:	invisible.
15:	id.
19:	id.
21:	id.
24:	id.
Sept. 17:	< g.
21:	id.
30:	> f. / < e.
Oct. 9:	> e. / < d.
15:	= d.
19:	1 step > c.
28:	> c. / < b.
Nov. 10:	id.
18:	1 step > b.
24:	id.
27:	= b.
30:	id.
Dec. 16:	< b. / > c.
18:	id.
26:	< c. / > d.
31:	id.

[1] *Vide the sketch in the Publications* A. S. P., No. 22, page 63.

W Pegasi.[1]

Jan.	1:	W = f.	
	7:	id.	
	10:	id.	
	13:	1 step > f.	
	22:	= e.	
	31:	= d.	
Feb.	2:	2 steps > d.	
	12:	= c.	
	26:	< b. / > c.	
Aug.	6:	invisible.	
	19:	id.	
	21:	< n (a star between W and h)	
	24:	id.	
	25:	id.	
Sept.	17:	id.	
	30:	id.	
Oct	1:	= n.	
	9:	id.	
	15:	id.	
	28:	= g.	
Nov.	10:	> g. / < f.	
	18:	1 step < f.	
	24:	id.	
	27:	id.	
	30:	id.	
Dec.	16:	> f. / < e.	
	26:	id.	
	31:	1 step > e.	

SS Cygni.[2]

Jan.	1..	6h P.M.	< f.
		8½	id.
	7..	6¼	= f.
	10..	6	3 steps > c. / 1 step < b.
		6¾	2 steps > c. / 2 steps < b.
	12..	6½	1 step > c. / 3 steps < b.
	13..	5¾	1 step < c.
	22..	6½	= g (the faint companion-star towards east.)
	31..	6½	invisible.
Feb.	2..	8	= g.
	12..	8½	< g.
	26..	8	= b.
Mar.	2..	9	< b. / > c.
	24..	8½	< g
May	5..	10	= d.
	13..	11½	< f.
	25..	11½	id.
June	10..	12½	< b. / > c.
July	19..	11	invisible.
Aug.	6..	11½	1 step > e.
	10..	12½	= g.
	19..	11	invisible.
	20..	10	= g.
	21..	10	< g.
	24..	11	= g.
	25..	10	id.
Sept.	15..	8½	> c. / < b.
	17..	8½	id.
	21..	9	< c. / > d.
	30..	8½	= f.
Oct.	1..	8½	= g.

[1] *Vide* the sketch in the *Publications* A. S. P., No. 60, page 23.
[2] *Vide* the sketch in the *Publications* A. S. P., No. 100, page 18.

Oct. 9..	8	< g.
15..	6½	id.
28..	8	> d. / < c.
Nov. 10..	6½	= g.
18..	6¼	< g.
24..	8½	= c.
Nov. 27..	7	1 step > c.
30..	5¾	= c.
Dec. 16..	5½	< f.
18..	6½	< g.
26..	6	id.
31..	7	= g.

Y Tauri (B. D. + 20°.1083).

The estimations in such a case, where one of the stars is red, are made easier by drawing out the ocular, the screw being given one turn. Then the star appears as a great disk. In the year 1905 this red star has shown only slight fluctuations near the brightness $8^m.2$ of the star b = B. D. + 20°.1073.

Jan. 1:	*Y* = b.
7:	id.
13:	id.
22:	id.
Feb. 2:	id.
26:	< b.
Mar. 24:	a little < b.
Apr. 1:	= b.
Oct. 28:	> b.
Nov. 10:	> b, almost = B. D. + 20°.1095 ($7^m.4$)
24:	= b.
Dec. 16:	> b.
17:	a little > b.
18:	id.
26:	id.
31:	id.

Nova Persei.

I have found no remarkable fluctuations, the star being almost stable between 10m.4 and 10m.6.

FIREBALLS.

Several years ago I directed attention to the fact that fireballs may be expected on December 12th. In my great catalogue on meteors from 1875-1905 this date returns eight times. In this period of thirty-one years fireballs appeared

On Dec. 9	1 year
" 10	2
" 11	5
" 12	8
" 13	5
" 14	2

FIREBALLS.

In the past year twenty-seven fireballs have been seen from stations in Denmark and surrounding countries, as follows:[1]

No.	Time.	Beginning.	End.	Mag.	Station.	Notes.
	h m	α δ	α δ			
1	Jan. 16, 7 50 P. M.	60° + 40°	82° + 3°	....	Holte	The meteor exploded in two pieces, following each other at a distance of 1°. The foremost was twice as long as the other, and remained visible an instant after the latter had disappeared.
2	Feb. 11, 11 25	.....	Western sky	....	Christiania and several places in Denmark.....	Exploding fireball lighted up the whole region in spite of moonshine. Five reports.
3	Mar. 20, 0 15	....	.....	...	Frederikstad and several other places in Norway	Gigantic fireball at *noon* over southeastern Norway. In Frederikstad the people were frightened by the loud detonation and ran out of the houses, thinking an earthquake had taken place. Somebody thought of a powder explosion. The fireball was seen in spite of the dazzling sunshine as a sparkling exploding meteor, leaving a large train for a moment. It disappeared 44 km. above a spot situated 18 km. NNE. from the named city, the path in the atmosphere being very steep, forming an angle of about 40° with the vertical. The fragments of the meteor have probably fallen into the sea. Twenty-one reports.
4	July 10, 12 27	NW.	.....	....	Copenhagen	Train, visible for four minutes, was straight in two, and undulated in the last two minutes.
5	Sept. 9, 7 41	15° South f. W. 55° altitude	45° South f. W. 40° altitude	¼ ☾	Vejle	Exploding meteor, one of the five or six pieces being green. Duration 4-5 seconds.
6	Dec. 12, 5 0	NE.	WSW.	....	Nordby (Fanö).	A large, slowly-moving meteor. Suddenly a train appeared, a cracking detonation was heard, also a plunge in the sea, and circular waves were seen, while the meteor was still visible in the sky. Duration 15 seconds.
7	Dec. 17, 9 33	NW.	270° + 35°	⅛ ☾	Wesselburnerkoog (Holstein).....	A yellow-white, at last red, fireball with a short tail. Explosion. Duration 1-2 seconds.

[1] The details of the seven most interesting of these meteors are here given.

Shooting Stars.

As usual, in the period August 9th-12th corresponding observations were arranged for from stations in Denmark. At six stations 59 paths of shooting-stars were mapped, but only three proved suitable for calculation. These three meteors have given the following results:—

FOR OBSERVATION.

No.	Time	Station.	Beginning.	Ending	Mag.	Observer.
	h m s		° °	° °		
1	Aug. 10, 10 17 50 P M.	Ribe	10 + 51	355 + 47·5	2	V. Dohn.
		Kolding		305 + 55	2	H. Nielsen.
		Odder	292 + 46.5	268 + 18	2	T. Köhl.
2	Aug. 10, 11 14 30	Ribe	356 + 27	349 + 26 5	3	V. Dohn.
		Odder	336 + 22	320 + 17	3	T Köhl.
3	Aug. 10. 11 43 15	Ribe	23 + 25	17 + 18.5	2	V Dohn.
		Odder	346 + 17	338 + 6.5	2	T Köhl.

FOR CALCULATION.

No.	Beginning			Ending.			Real Length of the Path.	Radiant.
	h	λ	φ	*h*	λ	φ	β	*AR Decl.*
		° ′	° ′		° ′	° ′		° °
1	103	2 21	55 49	70	2 54	55 31	60	36 + 52
2	235	0 2	54 47	168	1 28	54 50	116	10 + 27
3	95	1 12	55 22	82	1 24	55 9	32	86 + 52

In all cases Ribe-Odder has been used. As in the first case the end-point of the path was observed from three stations, two other combinations might have been used, and have given the following results:—

Stations.	Ending. *h*	λ	φ
Kolding-Odder	70	2° 56′	55° 30′
Ribe-Kolding	68	2 54	55 30

h and β are expressed in kilometers; λ is west longitude from Copenhagen; φ is north latitude; *h* is the altitude of the meteor above the Earth's surface.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1906.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter,	May 1,	11h 7m	A. M.	Full Moon,	June 6,	1h 12m	P. M.
Full Moon,	" 8,	6 10	A. M.	Last Quarter,	" 13,	11 34	A. M.
Last Quarter,	" 14,	11 3	P. M.	New Moon	" 21,	3 6	P. M.
New Moon,	" 22,	12 1	A. M.	First Quarter,	" 29,	6 19	A. M.
First Quarter,	" 30,	10 24	P. M.				

The Sun reaches the summer solstice and summer begins about midnight June 21st, Pacific time.

Mercury is a morning star on May 1st, rising somewhat less than an hour before sunrise. It reaches greatest west elongation on May 2d, and during the first half of the month the interval between the rising of the planet and of the Sun remains a little less than one hour. The conditions for visibility are not good, but the planet may possibly be seen in the morning twilight if the weather conditions are especially favorable. This greatest elongation (26° 46') is much larger than the average, since it comes about a week after perihelion; but the planet's distance south of the Sun makes the interval between the rising of the planet and the Sun rather small. *Mercury* reaches superior conjunction and becomes an evening star on June 8th. It then moves away from the Sun, and shortly after the middle of the month sets rather more than an hour after sunset. This interval increases to about an hour and a half by the end of the month; and the planet can then be easily seen in the evening twilight, although it will not reach its greatest east elongation until nearly the middle of July.

Venus is also an evening star and remains above the horizon on May 1st a little more than an hour and a half after sunset. At the end of June this interval has increased to a little more than two hours. The planet increases its distance from the Sun about 15° during this period, but it is moving along a part of the ecliptic somewhat south of the Sun's position. It moves from *Taurus* through *Gemini* and *Cancer* into *Leo*. At the beginning of May *Venus, Mars,* and *Jupiter* are all near together in *Taurus, Venus* being the farthest west.

Its more rapid eastward motion causes it to overtake and pass *Mars* on the morning of May 6th. At the time of nearest approach the planets are only 5′ apart, a distance less than twice the minimum separable by the naked eye. Unfortunately this very close approach occurs while the planets are below our horizon, but may be seen in the eastern hemisphere. *Venus* overtakes and passes *Jupiter* on the evening of May 11th. The minimum distance is a little more than 1°, about two diameters of the Moon, and occurs at a time when the planets are above our horizon. Then on the morning of May 18th *Mars* overtakes and passes *Jupiter,* the least distance being about the same as that at the conjunction of *Venus* and *Mars.*

Mars is still visible in the evening sky, but the Sun is drawing nearer to it. On May 1st it sets about two hours after the Sun; on June 1st, about an hour, and on July 1st, less than half an hour. The planet has now reached nearly its minimum of brightness, about that of the Pole Star, and it will not be easy to see it in the evening sky after June 1st. It will reach conjunction with the Sun about the middle of July, becoming a morning star, but will not be at all conspicuous for several months.

Jupiter during the early part of the May-June period is still conspicuous in the evening twilight. On May 1st it does not set until after 9 o'clock, but by June 1st, it remains above the horizon only about half an hour after sunset. It may be possible to see the planet on that date owing to its great brightness, but it soon draws too near the Sun for naked-eye view. It passes conjunction with the Sun on the morning of June 10th and becomes a morning star. By the end of June it rises about an hour before sunrise, and may be easily seen as a morning star. Between May 1st and June 30th it moves about 15° eastward in the constellation *Taurus.*

Saturn rises at about 3 A. M. on May 1st, and at about 11 P. M. on June 30th. It is therefore in fair position for early-morning observation. It is in the eastern part of the constellation *Aquarius* and moves about 3° eastward and northward, with constantly diminishing motion, until June 27th. It then ceases its eastward motion and begins to move westward. During the first half of the year the Earth has been continually

drawing nearer the plane of the rings, and the apparent minor axis is in June, only about one eighteenth of the major. The motion of the Earth during the latter half of the year will cause a slight increase in the apparent minor axis, but the Earth will pass the plane of the rings in 1907, and the apparent ellipse will reduce to a mere line.

Uranus rises before midnight on May 1st and shortly after 7 P. M. on June 30th. It retrogrades (moves westward) about 2° in the constellation *Sagittarius* during this period, and is a few degrees north of the "milk-dipper." No bright star is very near.

Neptune is in *Gemini,* and is in the western sky in the evening. It will reach conjunction with the Sun on July 2d.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Observations of Eclipse Shadow-Bands of August 30, 1905.

I regret exceedingly to say that through my oversight the valuable observations of shadow-bands made under my direction at the eclipse of August 30th, by Dr. Viggo Stroyberg, of Copenhagen, were omitted from the account of the Lick Observatory-Crocker Eclipse Expedition to Spain published in No. 106. I trust that Dr. Stroyberg will pardon the great injustice thereby done to his skill and enthusiasm. Following is quoted from his record of observation:—

"My place of observation was about 10 meters immediately north of the instruments. I had spread on the ground two white sheets of cloth, each between two and three meters square.

"Nearly one minute before totality the shadow-bands began. Their distance apart was about 15cm, and the dark lines were 3cm to 4cm broad. The velocity was so great that it was impossible to estimate it. I saw the lines straight and not undulating. I fixed the position of the lines with a long wooden bar, wnich I laid on the eastern sheet parallel to the lines. Their motion was southeastward and perpendicular to the bar. About 15 seconds before totality the shadow-bands disappeared.

"About 20 seconds after totality was over the shadow-bands came again. They had nearly the same motion and direction as before totality. The direction was fixed with another long wooden bar on the western sheet. They were very small and only a few of them could be seen. Their distances were nearly the same as before totality."

The azimuths of the two bars were measured and found to be, for the first, 35° south of west, and, for the second, 32° south of west. The directions of motion were therefore 55° and 58° east of south, respectively.

I do not venture an interpretation of these phenomena, nor a criticism of existing theories as to their cause; but it is of interest to note that their direction of motion was very nearly that of the Moon's shadow. W. W. Campbell.

THE SYSTEM OF CASTOR.

(Abstract from L. O. Bulletin No. 98.)

Both components of this interesting visual double star are of the Sirian type of spectrum. The absorption is more complete in the fainter star (a_1 *Geminorum*, magn.=3.7) than in the brighter (a_2 *Geminorum*, magn.=2.7). As a result the lines are more distinct in a_1 and more lines can be measured. But the less distinct lines in a_2 admit of slightly more precise settings being made.

The fainter component was shown to be a spectroscopic binary, with a period of nearly three days, by Professor BELOPOLSKY, of Pulkova, in 1895. The binary character of the brighter member of the system was discovered by the writer in October, 1904, from plates taken with the Mills spectrograph. The definitive orbits of both systems have been computed. The number of plates used in the case of a_1 was thirty-two, and an average of thirty-four lines was measured on each plate. The elements derived for a_2 depend upon forty-eight plates. The average number of measurable lines for this component was twenty-four. The full details of the calculations are given in the original paper. The resulting definitive elements for the two systems are as follows:

	a_1 *Geminorum.* (Fainter Component)		a_2 *Geminorum.* (Brighter Component.)	
Period =	2.928285 days		9.218826 days	± 0.000108
T =	J.D. 2416828.057	± 0.042	J. D. 2416746.385	± 0.021
e =	0.01	± 0.0066	0.5033	± 0.0112
ω =	102°.516	± 5°.120	265°.353	± 1°.730
K =	31.76	± 0.220	13.56	± 0.22
V =	−0.98km	± 0.15km	+6.20km	± 0.17km
$a \sin i$ =	1,279,000km		1,485,000km	
[*pec*] =	37.6		29.0	

For a_1 *Geminorum* the eccentricity is shown to be much smaller than supposed by BELOPOLSKY. In particular, BELOPOLSKY'S assumption of any rotation in the line of apsides is shown to be without foundation. The maximum effect of such a rotation for elements with an eccentricity of 0.01 would be but −0.3km, an amount too small to detect with certainty, in stars of this spectral type.

With future determinations of the elements of the visual

system it will eventually be possible to determine with considerable accuracy the parallax, masses, and orbital dimensions of this unique quadruple system. But the visual elements are absolutely indeterminate as yet, and assumptions as to the values of the parallax and other physical constants have no value.

It is not unreasonable to postulate, however, that the inclination of the orbital planes of both spectroscopic systems is roughly that of the main system. This is indeterminate at present. If we assume $i=63°$ as given by DOBERCK[1] in the elements which he regards as most probable (period=347 years), then the values for the semi-major axes of the spectroscopic systems are:—

a_1 *Geminorum*, $a = 1{,}435{,}000^{km}$
a_2 *Geminorum*, $a = 1{,}667{,}000^{km}$

These values are mere hypotheses, but it seems quite probable that the orbital dimensions of both systems are of the same order of magnitude. We would have in this case the interesting combination of two spectroscopic systems of approximately the same linear dimensions, one of which has the very great eccentricity of 0.50, while the orbit of the other is nearly circular. By the commonly accepted theories of stellar evolution this would seem to indicate that the brighter pair is much the older of the two systems. It has already approximated to the eccentricity of the main system, while its fainter companion system, of three times greater mass, still revolves in orbits almost circular.

Such an eccentricity as shown in a_2 is rarely met with except in those spectroscopic binaries which have as well a variation in their light. The tidal action in such a system, where at periastron the stars are but one third of their apastron distance apart, must be enormous. The attempt was accordingly made to test the constancy of the light of the brighter star by a series of observations with the smaller of the two Bruce polarizing double-image photometers belonging to the Lick Observatory. The observations were made with the photometer attached to the twelve-inch equatorial. There is no evidence of any variation from the present series. If it

[1] A. N., Vol. 166, p. 145.

exists at all, it must be very small, and would require a long series of observations to substantiate. There is no evidence, moreover, of any irregularity in the spectroscopic velocity curve. HEBER D. CURTIS.

COMET NOTES.

Seven new comets have been announced in the last five months: Comets *b*, *c*, *d*, and *e*, 1905, and *a*, *b*, and *c*, 1906. Three of these were discovered by photography and all were telescopic objects except GIACOBINI'S second comet (*c*) of the year 1905, which attained maximum brightness January 22, 1906, and would have been a fairly conspicuous naked-eye object but for its proximity to the Sun. The discovery of his first comet (*a*) of 1905 was followed by a lull of eight months in comet finding.

Comet *b* (SCHAER) was last seen and measured at this observatory by Mr. SMITH on December 29, 1905. Careful search with the 36-inch by Dr. AITKEN and the writer on January 5th, 20th, 26th, and 27th, under poor atmospheric conditions, failed to reveal the comet with certainty, though on the last date a suspected object was glimpsed in the predicted place.

Comet *c* 1905 (GIACOBINI) is still measurable, but is low in the western sky at sunset and difficult under the persistently bad weather conditions. The last measure secured here was on the evening of March 15th.

Comets *d* and *e* 1905 were discovered on the same photographic plate at Lowell Observatory two and four weeks respectively after the exposure. No search was made here, in the absence of sufficient search data.

Comet *a* 1906 (BROOKS) is still measurable, and is closely following the second orbit computed for it at the Students' Observatory.

Telegraphic announcement of the discovery of Comet *b* 1906 by KOPFF at Heidelberg was received March 5th. The comet was found in the photographic search for asteroids. Fortunately the weather permitted measures here on the 5th, 6th, and 7th. The comet's apparent motion is very small, as it is nearly in opposition and moving nearly parallel to the Earth's orbit (at an inclination of 1°). A fourth measure

was obtained on March 15th. Stormy or cloudy weather has prevented further observation.*

The latest comet, *c* 1906, was discovered at Melbourne by Ross, March 17th. Storm was brewing at the time on Mt. Hamilton and has prevailed continuously since, so that observation has been impossible. An orbit was computed at the Naval Observatory by Miss LAMSON from Eastern observations. The comet passed nearest the Sun on February 21st; it now sets a little north of the equator about two hours after sunset. It is improving somewhat in position for observation, but is diminishing in brightness; by April 1st it will be but half as bright as at discovery. This is one of the rare occasions when the orbit of a comet has been received before our first observation of it.

Since March 15th the Gerrish telegraphic cipher code, of Harvard College Observatory, has been employed in the transmission of astronomical messages, supplanting the more cumbersome Chandler-Ritchie Science Observer code, which has been in use for over twenty years. The new code substitutes for the ten digits the alphabetically formed syllables:—

ba	*de*	*fi*	*go*	*ku*,	*am*	*en*	*ip*	*ot*	*ux*
1	2	3	4	5	6	7	8	9	0

which can be memorized in the reading. If any of the data are omitted, the missing figures are represented by the syllable *ry*. The formation or translation of the numerical part of a telegram is accomplished by the simple exchange of numbers and syllables in order in filling out a printed blank form. There is no change of order or of units. The method of formation of the syllables renders the code practically error-proof; errors are less apt to occur, and when committed are usually apparent at a glance and corrected by inspection. A few explanatory plain words accompany each message.

JAMES D. MADDRILL.

ORBIT OF THE SEVENTH SATELLITE OF JUPITER.

Professor LEUSCHNER has recently derived an "Analytical Method of Determining the Orbits of New Satellites." An application of this method has been made by Mr. CHAMPREUX and myself to the case of the seventh satellite of *Jupiter*. The orbits given below are based upon PERRINE'S positions of

*Measured since on March 27th, after sending the note to printer.—J. D. M.

January 3d, February 8th, and March 6th (1905). The first set of elements was derived irrespective of any perturbations. The second set represents the first approximation to elements osculating February 8th by taking immediate account of the attraction of the Sun. The third set is the result of a close representation of the observations on the same basis.

The first set of elements is comparable with that of Ross *L. O. Bulletin* No. 82, giving practically the same representation for an observation of August 9th. The second and third sets, however, give the residuals:—

		II.	III.
(o—c)	△ p	= + 2°.7	+1°.6
	△ s	= + 5′.2	+8′.8

The computed positions being derived directly from the elements osculating for February 8th, without applying the solar perturbations from February 8th to August 9th. The solar perturbations are being computed for all observations secured since discovery by an adaptation of ENCKE's method of special perturbations in rectangular co-ordinates. With these perturbations it is expected that recent observations will be closely represented. Outstanding differences will serve for the correction of the third set of elements.

It is interesting to note that LEUSCHNER's method gives all the solutions possible on the basis of the three observations upon which the computation is based at one and the same time.

Elements of the seventh satellite of *Jupiter* (direct motion) referred to the Earth's equator, 1905.0:—

	Epoch, Feb. 8.6009 Gr. M. T.	Feb. 8.6009 Gr. M. T.	Feb 8.6009 Gr. M. T.
M	83° 17′ 57″	281° 13′ 48″	283° 04′ 04″
Ω	279 45 08	289 47 45	288 19 59
ω	6 38 42	189 15 19	187 29 41
i	26 27 14	25 39 42	25 39 23
e	0.12576	0.13195	0.12152
log μ°	0.15591	0.14885	0.14310
Period	251.142 days	255.538 days	258.942 days
*a	49′ 48″	50′ 20″	50′ 47″
(o − c) △ p	− 5°.6	+ 2°.7	+ 1°.6
(o − c) △ s	+ 33′.6	+ 5′.2	+ 8′.8

* a for log (*Jupiter's* distance) = 0.72124

RUSSELL TRACY CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT, March 26, 1906.

TWO STARS WHOSE VELOCITIES ARE VARIABLE.

The following two stars have been shown to have variable velocities in the line of sight from observations obtained with the Mills spectrograph:—

τ Ursae Majoris.

(α=9h 2m.7; δ=+63° 55'.)

Plate.	Date.	Velocity.	Measured by
1620D	1900 Jan. 22	— 5	CAMPBELL.
		—3.8	STEBBINS.
2377A	1902 April 15	— 10	REESE.
		— 10.2	STEBBINS.
2624E	Dec. 30	— 4	CURTIS.
		— 6.0	BURNS.
3107F	1903 Dec. 25	— 9.7	MOORE.
4181E	1906 Jan. 29	— 1	MOORE.
		— 1.5	BURNS.

The type of spectrum given by HARVARD is XII *C*. The binary character of this star was suspected by Mr. STEBBINS from the second plate and confirmed by the recent measures of Messrs. MOORE and BURNS.

μ Ursae Majoris.

(α=10h 16m.4; δ=+42° o'.)

Plate.	Date.	Velocity.	Measured by
309A	1897 Feb. 24	— 24	CAMPBELL.
		—27.4	BURNS.
689A	1898 March 31	— 20	CAMPBELL.
		— 22.0	BURNS.
1201C	1899 March 6	— 20	CAMPBELL.
		— 19.1	BURNS.
3208D	1904 April 11	— 16	MOORE.
		— 16.2	BURNS.
4151D	1906 Jan. 4	— 23	MOORE.

The spectrum is of type M. The variation seems to have been suspected earlier, but was confirmed by the recent approximate measures of MOORE and the definitive measures of the older plates by BURNS.

The plates are not properly distributed to give an idea of the period in the case of either star.

W. W. CAMPBELL,
J. H. MOORE.

COMET NOTES.

In comet affairs a very unusual state exists, no less than four being under observation at date. Three of these have been discovered this year, giving so far an average of one comet per month. Comet *a* 1906 was discovered by BROOKS at Geneva, New York, on the 26th of January. Two orbits of this comet were computed by Mr. CHAMPREUX and myself. According to the second set of elements, the comet is moving in a retrograde orbit whose plane is inclined 126° to the ecliptic. Its nearest approach to the Sun was December 22d of last year, when it was one hundred and twenty-one million miles from it. The elements and an ephemeris may be found in *L. O. Bulletin* No. 91.

The second comet of this year was discovered very nearly at opposition by KOPFF at Heidelberg, March 3d.

So far only a preliminary orbit of this comet has been derived. It is given in *L. O. Bulletin* No. 92. As soon as the weather permits another observation to be made at the Lick Observatory a second orbit will be computed. According to the preliminary elements, this comet is distinguished by having an inclination to the ecliptic of only 1° 8′, which is smaller than that for any other known comet. The nearest approach to the Sun, one hundred and twenty-two million miles, was on the 25th of December last year.

It may be of interest to computers to note that in the case of this comet, a very unfavorable one for the old methods, using LEUSCHNER'S short method, the elements were obtained by using six-place logarithms, in three and one half hours actual computing time after the receipt of the third observation.

The third comet of this year was discovered March 17th by Ross at Melbourne, Australia. Unfortunately, ever since its discovery cloudy weather has prevailed on this coast, so that up to date it has not been observed at the Lick Observatory.

Dr. MORGAN, of Morrison Observatory, Glasgow, Missouri, kindly sent observations of the 19th and 21st through the Harvard College Observatory. But before his third observation was available here preliminary elements were received from the Naval Observatory based upon observations of the 19th, 20th, and 21st. No observations, however, besides those of MORGAN were given out to the astronomical public. An orbit will be computed here from a longer arc.

RUSSELL TRACY CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT, March 24, 1906.

ELEMENTS OF COMET *b* 1906 (KOPFF).

A third observation of this comet to serve for the determination of the orbit from longer intervals than those used in the first preliminary orbit (*L. O. Bulletin* No. 93) was secured by Mr. J. D. MADDRILL at the Lick Observatory on March 27th during a clear spell in the recent stormy weather. This observation, as well as the others on which a second orbit was based, was kindly communicated to the Students' Observatory by the Lick Observatory. The three positions, all of which are by MADDRILL, are as follows:—

1906	Gr. M. T.	App. α	App. δ
March	5.7743	$11^h\ 35^m\ 00^s.8$	$+1^\circ\ 42'\ 40''$
	15.76865	11 30 41 .3	1 57 33
	27.7448	11 25 50 .7	+2 14 40

From these we have derived the following elements:—

$T = 1905$ October 20.8024 Gr. M. T.
$\omega = 159^\circ\ 03'\ 06''$
$\Omega = 342\ 09\ 54$ } 1906.0
$i = 4\ 12\ 37$
$q = 3.31645$

These elements leave a residual of $-2''$ (O.—C) in the first and third right ascensions. It will require a still longer arc to determine the elements to any degree of certainty. The small value of the residuals for the parabolic orbit does not as yet warrant the determination of elements without hypothesis regarding the eccentricity.

The perihelion distance of the first preliminary orbit was $q=1.3$. The new solution was made on the basis of the first preliminary orbit by the differential formulæ of LEUSCHNER's short method, which were found to be fully, although

slowly, convergent in spite of the large corrections to the original elements. As a check on the results the geocentric distance at the middle date was independently derived by direct computation from the given positions.

R. T. CRAWFORD,
A. J. CHAMPREUX.

BERKELEY ASTRONOMICAL DEPARTMENT, March 31, 1906.

ECLIPSES OF THE FIRST SATELLITE OF JUPITER.

The following disappearances and reappearances of the first satellite of *Jupiter* were observed with the 3½-inch finder of the photographic telescope, the magnifying power used being 60. Observations were secured whenever the weather permitted.

Ec. Dis.	Am. Eph and N. A. Wash. M. T.			Observed. Wash. M. T.			Remarks.
1905 Nov. 6	11^h	24^m	23^s	11^h	24^m	16^s	
" 11	18	50	22	18	49	47	Hazy.
" 13	13	19	6	13	18	13	Small transparent
" 20	15	13	58	15	11	53	cloud over planet.
Ec. Re.							
Nov. 27	19	17	27	19	19	20	
Dec. 6	15	41	23	15	41	13	
" 8	10	10	17	10	10	14	
" 13	17	36	45	17	36	43	

STURLA EINARSON.

BERKELEY ASTRONOMICAL DEPARTMENT, March 26, 1906.

ON THE PARALLAX OF THE CENTRAL STAR OF THE ANNULAR NEBULA IN LYRA.

In a recent article on the Annular Nebula in *Lyra* (*Monthly Notices*, Vol. LXVI, p. 106) Mr. BARNARD draws the following conclusion concerning my investigation of the parallax of the central star: "As Dr. NEWKIRK's parallax for the central star depends upon the proper motion which he determined, and which is shown not to exist, the parallax itself must be fallacious."

This conclusion is not justified unless a solution of the equations of condition, with the proper-motion terms omitted, indicates that no measurable parallax exists. Such a solution from the eight pairs of comparison stars gives:—

Weighted mean parallax $=+0''.067=0''.02$ (mean error)

The result obtained when proper motion terms are included in the equation of condition is:—

$$\text{Parallax} = +0''.10 \pm 0''.02 \text{ (mean error)}$$

If instead of averaging the eight values, equations of condition be set up for the simultaneous determination of the parallax and the effect of chromatic dispersion, the above value of the parallax is reduced by 0″.003 only.

I am fully aware of the uncertainty which attaches itself to investigations of stellar parallax, and realize the desirability of a thorough test of my results. An investigation of proper motion alone, however, does not seem likely to throw much light on the value of the parallax.

Most of the plates used in my parallax investigation were exposed during the year 1899 and 1900, and the series could not, therefore, form a good basis for an investigation of proper motion. This is explicitly stated on page 15.

The evidence of proper motion which was presented as a supplement to the parallax investigation rested mainly on observational material not used in the parallax determination. A note regarding this subject has been sent to the *Monthly Notices* of the Royal Astronomical Society.

B. L. NEWKIRK.

BERKELEY ASTRONOMICAL DEPARTMENT, March 31, 1906.

FROM THE STUDENTS' OBSERVATORY.

Arrangements have been completed for two courses in astronomy to be given at the summer session of the University of California. The courses are described in the announcement as follows:—

1. *Modern Astronomy*: An illustrated lecture course, aiming to present in non-technical language the fundamental facts and principles underlying the science of astronomy, with some of the methods and results of modern research.

2. *Observatory*: Lectures on practical astronomy and observatory work, illustrative of course 1, with the reflector, refractor, the photographic telescope, the zenith- and transit-telescope, sextant, etc.

These courses are to be given by Dr. NEWKIRK.

A. O. L.

During the current term the Berkeley Astronomical Department is conducting for the first time a course in the reduction and measurement of astronomical photographs, with an enrollment of four graduate students. The course is being given by Dr. NEWKIRK. With the completion of the photographic telescope with two portrait lenses and the acquirement of a Repsold measuring-apparatus, the department now has this branch of instruction thoroughly organized.

A. O. LEUSCHNER.

THE SPECTROSCOPIC BINARY, *U Aquilae*.

In the fall of 1905 several spectrograms of the variable star *U Aquilae* were obtained with the one-prism spectrograph. Rough measures give a velocity-curve of double amplitude of about 25^{km} and a period coinciding with the period of light variation, which is 7.02 days. S. ALBRECHT.

March 26, 1906.

THE AWARD OF THE GOLD MEDAL OF THE ROYAL ASTRONOMICAL SOCIETY TO PROFESSOR W. W. CAMPBELL.

In the last number of these *Publications* brief mention was made of the award of this medal to Dr. CAMPBELL. Since then an advance copy has been received of the address of Mr. W. H. MAW, President of the Royal Astronomical Society, in making the award and of the response of Mr. WHITELAW REID, American Ambassador, in accepting it in the medalist's name.

Mr. MAW's address, after a brief sketch of the history of the determination of the radial velocities of the stars and of the discovery of spectroscopic binary stars, gives in more detail Dr. CAMPBELL's contributions to the development of these departments of astronomical research. After speaking of the Mills spectrograph, designed by Dr. CAMPBELL, of the great number of spectrograms taken with it, and of the fact that seventy-five, or more than one half, of the known spectroscopic binaries stand to the credit of the Lick Observatory (including the D. O. Mills Expedition to the Southern Hemisphere), twenty-nine being discovered by Professor CAMPBELL himself, and five more by him in conjunction with another observer, Mr. MAW continues:—

"Nor is the importance of our medalist's work on the determination of radial velocities and the characteristics of spectroscopic binaries to be judged simply, or even chiefly, by its amount. Of even greater value is the influence which he has personally exerted on the accuracy of observations of radial velocity."

It is shown that the advance in accuracy of such measures is largely due to improvements in the optical and mechanical construction of spectrographs introduced by Dr. CAMPBELL, to the use of iron as a comparison spectrum, and to refinements in methods of plate measurements also due to him. Special attention is called to Dr. CAMPBELL'S discovery of and researches on the interesting spectroscopic binary systems—*ζ Geminorum*, *Capella*, and *Polaris;* to his discussion of the Sun's way, based on data secured with the Mills spectrograph, and to his work on the Wolf-Rayet type stars and on *Mira Ceti.*

The important part taken by Professor CAMPBELL in recent solar eclipse work is dwelt upon, and brief mention is also made of his researches on nebular spectra, the spectra of comets, and of temporary stars, for the last named of which the Lalande prize was awarded to him in 1903.

The address is too long to quote from satisfactorily, but should be read by all who are interested in the progress of the astrophysical work of the Lick Observatory.

It is an interesting coincidence that the American Ambassador, Mr. WHITELAW REID, who received the medal for Dr. CAMPBELL, is the son-in-law of Mr. D. O. MILLS, to whose generosity the Mills spectrograph and the Mills Expedition to the Southern Hemisphere are due. Mr. REID'S short address will be of general interest, and is therefore reprinted in full:—

"It is a pleasure to serve as the medium for transmitting this mark of your distinguished approval to my countryman on the far Pacific Coast of the United States; and the personal circumstances, to which you have made such gracious allusion, give the duty a special zest.

"Professor CAMPBELL will certainly value your decoration as highly as a soldier or statesman would value one sent him by a sovereign. In his name I beg to tender profound thanks to the Royal Astronomical Society for this medal; and to you, sir, as its President, for the learned and generous appreciation of his work to which we have just listened.

"I am warranted in adding also the thanks of the Lick Observatory and of the great University of California of which it forms a part.

"My country is proud of every advance in art or science made by her sons,—prouder of these than of triumphs in trade or in war,—and will be gratified that this high recognition for service to one of the

noblest of sciences comes from a land to which we are so closely related and to whose judgment we attach such importance."

R. G. A.

THE CROSSLEY REFLECTOR PHOTOGRAPHS OF EROS.

The measurement and reduction of the Crossley reflector photographs of the minor planet *Eros* taken in 1900-1901 for determining an improved value of the solar parallax, began at Mt. Hamilton in December, 1905, in charge of Dr. PERRINE. Miss FREDRICA CHASE, formerly of Vassar College, and Miss A. M. HOBE, formerly of the Berkeley Astronomical Department, are engaged in the work on the Carnegie Institution foundation. Its completion is expected to require two and one half years. It is planned that these photographs shall furnish their own value of the parallax; nevertheless it is hoped that the measures will be available and valuable for combination with observations made at other institutions.

W. W. CAMPBELL.

THE DEATH OF PROFESSOR LANGLEY.

It is with deep regret that we learn of the death of Professor SAMUEL PIERPONT LANGLEY on February 27th, at the age of seventy-one. Professor LANGLEY became Director of the Allegheny Observatory in 1867 and Secretary of the Smithsonian Institution in 1887. His interests in scientific subjects were wide, and his contributions to all subjects receiving his special attention were of the highest importance. At a memorial meeting of the Board of Regents of the Smithsonian Institution recently the following resolutions were adopted:—

"*Resolved*, That the Board of Regents of the Smithsonian Institution express their profound sorrow at the death, on February 27, 1906, of SAMUEL PIERPONT LANGLEY, Secretary of the Institution since 1887, and tender to the relatives of Mr. LANGLEY their sincere sympathy in their bereavement;

"That in the death of Mr. LANGLEY this Institution has lost a distinguished, efficient, and faithful executive officer under whose administration the international influence of the parent Institution has been greatly increased, and by whose personal efforts two important branches of work have been added to its care—the National Zoological Park and the Astrophysical Observatory;

"That the scientific world is indebted to Mr. LANGLEY for the

invention of numerous important apparatus and instruments of precision, for numerous additions to knowledge, the more especially for his epoch-making investigations in solar physics, and for his efforts in placing the important subject of aerial navigation upon a scientific basis;

"That all who sought the truth and cultivated science, letters, and fine arts, have lost through his death a co-worker and a sympathizer;

"That the Executive Committee be requested to arrange for a memorial meeting to be held in Washington;

"That Doctor ANDREW D. WHITE be invited to prepare a suitable memorial which shall form part of the records of this board."

It is planned to publish later a more detailed account of Professor LANGLEY'S contributions to astronomy.

W. W. CAMPBELL.

REPORTS OF OBSERVATORIES.[1]

Some years ago the Committee on Publication of the Astronomical Society of the Pacific inaugurated the plan of obtaining annual reports from the observatories of the Pacific Coast. The plan met with success, and has been carried out with some modifications and interruptions, ever since. The committee hopes to be able to publish, from now on, reports from all the observatories, both great and small, situated between the Rocky Mountain region and the Pacific Coast.

In addition to the observatories from which reports are printed below, there are a number of others possessing small equipments which are used chiefly for purposes of instruction. Among these may be mentioned the observatory of the University of Washington at Seattle, which has a 6-inch refractor, chronometer, and sextant; the observatory of the University of Oregon, at Eugene, which is provided with transit, sidereal clock, and sextant; the observatories of the University of the Pacific at San Jose and of Santa Clara College, both of which have small refractors and minor instruments; the Chabot Observatory, which forms a part of the public school system of the city of Oakland, and possesses an 8-inch refractor, together with a very complete equipment of accessory instruments; the Coast and Geodetic Survey Observatory in San Francisco, containing a transit and a zenith telescope, which is a base station for telegraphic longitude work. Captain ROGERS, who is in charge of the observatory, reports that no work was done there during 1905, the last work being the Transpacific difference of longitude, San Francisco-Manila, in 1903-4.

CHAMBERLIN OBSERVATORY, DENVER, COLORADO.

During the year 1905 the chief observations of the Chamberlin Observatory were upon the comets then visible. Experiments were also made about special methods of noting time and certain varieties of personal equation.

H. A. HOWE, *Director.*

[1] Arranged alphabetically according to name.

INTERNATIONAL LATITUDE OBSERVATORY, UKIAH, CALIFORNIA.

The programme of the International Geodetic Association for observing variations of latitude was continued throughout 1905 without modification or interruption. Good observing weather prevailed throughout the year except during the month of January. The rainfall for the year was 29.1 inches. The maximum temperature was 113° F., on July 7th; the minimum, 21°, on December 24th. During the early part of July a "warm spell" prevailed, during which the following maximum temperatures were observed on a thermometer hanging on the north side of the Observatory inside the surrounding latticework.

July 3, 100°	July 7, 113°
4, 101	8, 108
5, 108.5	9, 104
6, 107	10, 103

The three longest intervals without observations were ten nights in March, seven in April, and eight in November. The first and third of these were caused by unfavorable weather and the second by a combination of unfavorable weather and absence of the observer from the station.

The following table gives a summary of the observations made for the variation of latitude. The first column contains the number of determinations made each month, the second column the number of nights upon which observations were made, the third column the number of complete nights (16 determinations), the fourth column the greatest interval each month during which no observations were obtained.

1905.	Pairs.	Nights.	Nights.	Nights.
January	144	13	6	6
February	231	17	11	5
March	184	14	9	10
April	189	18	8	7
May	224	17	10	5
June	214	20	10	3
July	247	17	13	3
August	280	19	16	4
September	254	17	14	4
October	251	17	14	4
November	164	12	8	8
December	178	13	8	4
Totals	2560	194	127	
Means	213	16	10.5	5

The probable error of a single determination of the latitude varied, as in previous years, between $= 0''.10$ and $= 0''.11$.

SIDNEY D. TOWNLEY, *Astronomer-in-Charge.*

LICK OBSERVATORY, MT. HAMILTON, CALIFORNIA.

The output of observational and related results along the lines of our current programme was considerably reduced for the year 1905 on account of several unusual conditions.

The total solar eclipse of August 30, 1905, was to occur under a combination of circumstances as to duration, location, season, and probable weather, so favorable that we could not hope to see them equaled for a great many years to come. The burden of preparing the very extensive equipments of the expeditions to Labrador, Spain, and Egypt fell upon Messrs. CURTIS, CAMPBELL, and PERRINE, and much of their time from January 1st until shipment was made in June was devoted to this important subject. Minor parts in these preparations were assigned to several other members of the staff.

Dr. CURTIS was absent, in connection with the Labrador expedition, from June to October. After his return to Mt. Hamilton his duties consisted largely in preparing additional plans and equipment for the D. O. Mills expedition to Chile. He left on December 27th to take charge of the expedition, on Cerro San Cristobal, Santiago, Chile, for a period of five years.

Messrs. CAMPBELL and PERRINE were absent from June to November, in connection with the Spanish expedition.

Professor HUSSEY left Mt. Hamilton on June 1st, was absent four months in connection with the Egyptian expedition, and returned to this country early in October to assume his new duties as Director of the Detroit Observatory.

The general plans and results of the three eclipse expeditions have been described already in these *Publications* (Nos. 105 and 106), and it does not seem necessary to repeat them here, although they form an important part of our work in 1905.

The observing programme of the D. O. Mills expedition was continued uninterruptedly through the year, except that Acting Astronomer WRIGHT was alone in the work after Sep-

tember, Assistant H. K. PALMER having returned to this country. The exact number of spectrograms for radial velocities of the stars obtained in the year will not be known to me for a few weeks yet, but it amounts to several hundred. All of these have been measured approximately and many of them definitively.

About one year ago Mr. MILLS arranged, with great generosity, to continue the expedition for five additional years, and at the same time to improve and add to its equipment.

The meridian-circle department, in charge of Astronomer R. H. TUCKER, obtained results as follows:—

The measurement of the graduation errors of the 10′ divisions of the fixed circle of the Repsold instrument was completed in April. The preliminary reductions had been kept up during the progress of the work, which began eighteen months earlier, and the final corrections were promptly derived and published in *L. O. Bulletin* No. 85. The method of simultaneous reading of both circles was employed up to this point, all the 10′ divisions of a single degree of the movable circle being compared successively with the 10′ divisions of the fixed circle.

Mr. ELLIOTT SMITH, Carnegie Assistant for two years ending July 1st, took part in the measures and in the corresponding computations.

Some measures were made of the intermediate 2′ divisions, extending over a degree of each circle. One observer reads alone in this process, which consists of direct measurement, by means of the circle microscopes, from the nearest 10′ divisions. Special 2′ divisions required in the observation of the fundamental programme have also been measured. The complete measurement of all the 2′ divisions is not at present contemplated.

Observations of a fundamental character were begun in July, including several co-ordinated schemes. Circumpolar stars, including *Polaris,* are observed at successive upper and lower culminations. Zenith stars are included in each series for the investigation of certain classes of systematic error. Stars of large zenith-distance, north and south, are observed for test of the corrected refractions, already investigated here. And the design is to provide fundamental determinations of

a series of stars from the pole to high southern declination, which shall serve as the basis for the observation of the places of a large number of fundamental stars.

Observations were made for about half of a list of latitude stars used by Professor C. L. DOOLITTLE, of the Flower Observatory. Both co-ordinates were determined, as it is not considered to be practical economy to observe declination only.

The reductions of the observations of the zodiacal list, completed in 1904, were carried on during the past year nearly to completion.

The magnitude equation in the right ascension of the *Eros* stars was investigated, and the results were published in *L. O. Bulletin* No. 72.

Astronomer W. J. HUSSEY's observational work at Mt. Hamilton before June 1st included about 300 complete measures of double stars and the discovery of approximately 100 new pairs.

Dr. R. G. AITKEN's work for the year was as follows:—

Observing:

(1) 1,350 measures of double stars with 36-inch telescope. The observing-list included the more important known binary systems. 130 stars discovered, but only partly measured, by W. J. HUSSEY, and the new stars discovered by the observer.

(2) 340 new double stars discovered with the 12- and 36-inch telescopes. These are all under 5″, 76 per cent. of them under 2″, and 31 stars under 0″.25. This work involved the examination of over 11,000 stars.

(3) Measures of the satellites of *Uranus* and *Saturn* and Satellite V of *Jupiter* with the 36-inch telescope. Also observations of eclipse phenomena of *Saturn's* satellites.

(4) Measures of comets, *a*, *d*, and *e* 1904 and *a* and *b* 1905, mostly with the 12-inch telescope, a few with the 36-inch telescope.

Computing:—

(1) Elements and ephemeris of Comet *d* 1904.
(2) Elliptic elements and ephemeris of Comet *e* 1904.
(3) Orbit of β 395=*Ceti* 82.
(4) Orbit of Σ 1998=ξ *Scorpii*.
(5) A catalogue of the orbits of visual binary stars.

One hundred and eighty-nine negatives were obtained with

the Crossley reflector, principally by Dr. PERRINE, astronomer in charge of the instrument. They consisted chiefly of photographs of the faint satellites of *Jupiter* and *Saturn* and of the satellite of *Neptune*. Those relating to *Jupiter* led to Dr. PERRINE'S discovery of the sixth and seventh satellites and formed the basis for the determination of their orbits. From June to November the Crossley reflector was in immediate charge of Mr. SEBASTIAN ALBRECHT, who reobserved the new satellites after their conjunction with the Sun, securing a considerable number of excellent plates. He also obtained a few observations of *Saturn's* ninth satellite. The photographs obtained by Mr. ALBRECHT numbered about sixty. Measures and reductions of several of the summer plates were made by Mr. ALBRECHT and Mr. SMITH.

The performance of the new mounting of the Crossley reflector, completed late in 1904, has fully met expectations. Dr. PERRINE'S description of the instrument is contained in *Lick Observatory Bulletin* No. 78.

The work with the Mills spectrograph has been prosecuted continuously throughout the year. The observational part was borne largely by Dr. MOORE, who was in charge of the spectroscopic department during the absence of the eclipse observers. Dr. CURTIS observed regularly during the months that he was on the mountain, and Mr. BURNS assisted occasionally. Altogether 475 spectrograms were obtained with the three-prism Mills spectrograph. Mr. K. BURNS, Carnegie Assistant, measured 398 plates definitively; Dr. CURTIS measured about 75 definitively and 30 approximately, and Dr. MOORE measured 75 definitively and 200 approximately. Dr. TURNER, of the University of the City of New York, spent the months of July and August here, assisting in the observations and acquiring experience in the measurements and general methods of radial velocity determinations.

Dr. CURTIS made a special study of the quadruple system of *Castor*, based on spectrograms obtained with the Mills spectrograph.

One hundred and fourteen spectrograms were made with the one-prism instrument; 28 of *X Sagittarii* and 3 of *Nova Aquilae* No. 2, by Dr. MOORE; and 34 of *T Vulpeculae*, 40 of

Y Ophiuchi, and 9 of *U Aquilae*, by Mr. ALBRECHT, in connection with his thesis work looking to the degree of Doctor of Philosophy. These have nearly all been measured by the observers.

Mr. J. D. MADDRILL, Fellow, made observations with the Rumford photometer as follows: Variable stars and the asteroid *Urda*, 118 comparisons with several neighboring stars, involving about 4,800 settings; *Pleiades* standards on four nights, requiring 300 settings; and for the effects of sky-illumination, position-angle, and other variable factors, on eight nights, involving 400 settings. Eighteen eclipses of *Jupiter's* satellite I were observed for Professor NEWCOMB. The positions of *Nova Aquilae* No. 2 and of *Urda* were determined with the micrometer of the 12-inch refractor.

Messrs. ALBRECHT and BURNS secured photographs of the Sun, with the camera of 40-foot focus, during the twenty days preceding and following the eclipse date, August 30th.

Mr. ELLIOTT SMITH, Fellow from July 1st, assisted in the observations with the Crossley reflector, in the reduction of Dr. AITKEN'S satellite and comet observations, and made 15 micrometric observations of comets, 12 of asteroids, and 9 photographs of Comet *c* 1905.

Lick Observatory Bulletins Nos. 67 to 88 were published within the year.

No reference is made in the foregoing abstract to a large number of minor duties discharged by the members of the staff during the year. W. W. CAMPBELL.

LOWELL OBSERVATORY, FLAGSTAFF, ARIZONA.

Visual observations on *Mars* at the last opposition were begun by the Director on January 13th and continued until August 15, 1905. Previous to this observations on the planet were made by Mr. LAMPLAND, beginning about the middle of September, 1904. As at the earlier oppositions, the observational data consisted of drawings, notes and measures. From the experience gained by Mr. LAMPLAND in planetary photography on *Jupiter* and *Saturn* during the two years previous to this opposition, it was possible to supplement the above data with photographs of the canals and other surface markings of the planet.

From January 13th to August 15th, the most favorable

months of the opposition, the series of drawings, notes, and measures give nearly an unbroken record of the phenomena presented by the disk from day to day. Opposition occurred on May 8th, so that the series of continuous observations cover a period of about four and three months before and after opposition respectively. The observations at this opposition confirm and extend those made at the earlier oppositions. In particular may be mentioned the observations on the double canals, the varying visibility of the surface-markings on different parts of the disk with the planet's season and the canal development brought to light by the observations made in 1903. For a detailed account of the observations and discussion of the various phenomena reference is here made to the *Annals* and *Bulletins* of this observatory.

A new determination of the position of the axis of *Mars* will be found in *Bulletin* No. 24. The investigation takes into account the determinations of SCHIAPARELLI, LOHSE, CERULLI, STRUVE, and all measures made by the writer, including those made at the opposition of 1905. (See *Bulletin* No. 24.)

From May 10th until June 30th, visual observations and photography were carried on together. After this photographs were made at intervals until the middle of July. The later photographs, however, are much inferior to the earlier ones, due to the smallness of the disk and the increased phase. Several hundred images of the planet were obtained, and a great many of these have good definition, showing the canals and other surface-markings distinctly. A preliminary account of the work has been given in *Bulletin* No. 21, and in a paper presented to the Royal Society. A word in regard to the quality of the observing conditions here may not be out of place. The steadiness and transparency of the atmosphere may be judged from the large amount of detail shown in the planetary negatives with the large equivalent focal length used (about 148 feet). As further evidence in regard to the transparency may be mentioned the addition of faint stars to the chart of faint stars visible in the large telescopes of the Harvard, Washington, and Lick observatories. (See *Popular Astronomy*, Vol. XIII, No. 7.)

During the period covered by the *Mars* observations *Venus*

was observed from time to time, taking advantage of the most perfect conditions.

Various theories have been advanced from time to time explaining certain Martian phenomena, notably the double canals, as being optical products of one sort or another, or illusions. It has been deemed important to investigate these theories critically in order to obtain definite knowledge of the true value of Martian observational data and the deductions made from them. Theory and experiment, at the telescope and elsewhere, as well as the direct results of observation, applicable as criteria for tests of these theories, show conclusively that the phenomena in question cannot be spurious results of observation. Bearing directly on the problem of the double canals, the separative power of glasses has been dealt with from the standpoint of theory and experiment in *Bulletin* No. 5, and in *Popular Astronomy* (Vol. XII, No. 9). The diplopic, interference, and illusion theories have been discussed in detail in *Bulletin* No. 15.

The programme of spectroscopic work, in charge of Mr. SLIPHER, has included: (*a*) Investigations on the spectra of the planets *Venus*, *Mars*, *Jupiter*, and four brighter satellites —*Saturn*, *Uranus*, and *Neptune*—for study of their atmospheres. By the use of isochromatic plates and specially prepared plates sensitive to a large part of the less refrangible region of the spectrum, it was possible to photograph the spectra of these planets far into the red, including the region in which atmospheric absorption bands exist. For comparison-spectrum that of the Moon or Sun, at an equal altitude, has always been used, with exposures producing as nearly as possible the same density of deposit as that of the planet. Hygrometric conditions were also carefully considered in this work, so that the relative intensities of the absorption bands in the two sources might be directly comparable. For a detailed discussion of these results the reader is referred to *Bulletins* Nos. 13, 16, and 17. (*b*) Radial velocity determinations have included a short miscellaneous list of stars and the ten standard velocity stars proposed by Professor FROST (*Astrophysical Journal*, Vol. XVI, p. 169). The published results of this work will be found in *Bulletins* Nos. 11 and 23, and in the

Astrophysical Journal (Vol. XX, No. 2; Vol. XXII, Nos. 1 and 5.)

During January and February of this year Mr. LAMPLAND has made a series of measures for position on the sixth satellite of *Jupiter*.

General celestial photography and micrometric work has been carried on by Mr. DUNCAN, Lawrence Fellow at this observatory. Photographic work for charting purposes was done with the 24-inch refractor and a large portrait-lens mounted on its tube. The photographs with the visual telescope were made in the focal plane on isochromatic plates without color screen, the secondary spectrum of all but the brightest stars being too faint to affect perceptibly the plate.

Mr. DUNCAN made a series of photographs of Comet *c* 1905 (GIACOBINI) with the large portrait-lens and a smaller lens of about 8 inches focal length. These plates show the development of the comet from the first appearance of the tail until a short time before perihelion passage, when the tail was shown to have attained a length of over eleven degrees. A series of measures of comets GIACOBINI, BROOKS, and KOPFF is still in progress.

In May, 1905, the old Bond spring governor driving-clock of the 24-inch telescope was replaced by a large and powerful clock of the conical-pendulum type, made by WM. GAERTNER & Co., of Chicago. The excellent performance of this clock contributed largely to the sucess in obtaining the photographs of the canals of *Mars*.

The varied programme of spectroscopic work carried on makes it necessary that the spectrograph be adjustable for work in different regions of the spectrum. The original mounting of the prisms did not give the rigidity and stability required, unless the clamping screws on the top plate of the prism mountings were screwed down so tight that the pressure destroyed the homogeneity of the prisms. To remedy this defect the instrument is being remodeled by BRASHEAR, according to designs by Mr. SLIPHER. The prisms are being remounted and the collimator provided with a curved slit.

The mounting of the 6-inch Clark refractor is being remodeled and provided with driving mechanism, in the hope

that this instrument may be utilized as a guiding telescope for photographic work with portrait lenses.

PERCIVAL LOWELL, *Director.*

NAVAL OBSERVATORY, MARE ISLAND, CALIFORNIA.

The equipment of the observatory consists of two Stackpole broken-back transits used in the time service; four standard clocks, two sidereal and two mean-time, and a mean-time transmitter used in sending out the time; and a 5-inch Clark refractor of the type devised for observing the transit of *Venus*. In addition to these instruments there are others used in nautical and meteorological work and a large number of chronometers belonging to the Navy.

The observatory was established primarily for furnishing the time to the Navy Yard and the west coast, and for investigating the rates of chronometers. The time is furnished daily, except Sundays and holidays, to the Western Union Telegraph Company, and goes over the wires as far east as El Paso, Texas, and Omaha, Nebraska; so that it reaches all points west of the Rocky Mountains.

During the year from fifty to one hundred chronometers are investigated and issued to the naval service. Some of these are issued to ships of the Pacific fleet, assigned to the west coast of the United States, but rather more go to the Naval Station at Cavite, Philippine Islands, for the use of the Asiatic fleet.

A new observatory with more complete equipment has been recommended for several years, but provision for it has not yet been made by Congress. T. J. J. SEE.

SOLAR OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON, MT. WILSON, CALIFORNIA.

The purpose of the Solar Observatory may be defined as follows:—[1]

(1) The investigation of the Sun (*a*) as a typical star, in connection with the study of stellar evolution; (*b*) as the central body of the solar system, with special reference to possible changes in the intensity of its heat radiation, such as might influence the conditions of life upon the Earth.

[1] The detailed program of solar research is given in "Contributions from the Solar Observatory," No. 3 (reproduced in a recent number of the Publications of the Astronomical Society of the Pacific.)

(2) The choice of an effective mode of attack, involving (*a*) the application of new methods in solar research; (*b*) the investigation of stellar and nebular phenomena, especially such as are not within the reach of existing instruments; and (*c*) the interpretation of these celestial phenomena by means of laboratory experiments.

(3) The design and construction of a large reflecting telescope and of new types of instruments peculiarly adapted for the purposes in view, with special reference to the possibilities of research through the study of celestial objects under laboratory conditions.[1]

(4) The accomplishment of the foregoing purposes at a site where the atmospheric conditions have been shown to be exceptionally favorable: Mt. Wilson (5,886 feet), in Southern California, (lat. +34° 13′ 26″; long. W. 118° 3′ 40″).

(5) The furtherance of international co-operation in astrophysical research through the invitation to Mt. Wilson, from time to time, of investigators specially qualified to take advantage of the opportunities afforded by the Solar Observatory.

Staff.—My principal associates on Mt. Wilson are FERDINAND ELLERMAN and WALTER S. ADAMS, assistant astronomers, and HENRY G. GALE, assistant physicist. Mr. ADAMS has been appointed superintendent of the computing division, and the staff of computers is now being organized. At the Pasadena instrument-shop the work of construction is carried on under the supervision of Professor G. W. RITCHEY, astronomer and superintendent of instrument construction.

Professor WINSLOW UPTON, Director of the Ladd Observatory of Brown University, and Professor L. H. GILMORE, of Throop Polytechnic Institute, were engaged in special work at the Solar Observatory during the summer of 1905.

During 1905 the following expeditions have conducted observations on Mt. Wilson in co-operation with the Solar Observatory:—

Hooker Expedition—EDWARD E. BARNARD, astronomer of the Yerkes Observatory, in charge.

[1] See "The development of a New Observatory," Publications of the Astronomical Society of the Pacific, Vol. XVII, p. 41, 1905.

Smithsonian Expedition—CHARLES G. ABBOT, aid acting in charge of the Smithsonian Astrophysical Observatory, in charge; LEONARD R. INGERSOLL, University of Wisconsin, assistant.

Investigations in progress.—Although the programme of observations must naturally be a restricted one until the completion of the instrumental equipment, it has nevertheless been possible to commence systematic work in five departments: (1) daily photography of the Sun with the photoheliograph; (2) daily photography of the Sun with the spectroheliograph; (3) photography of the spectra of sun-spots and flocculi; (4) photography of stellar spectra with a spectrograph of high dispersion; (5) laboratory investigations. The Snow telescope has been employed in all of the solar and stellar work; various tests of this instrument have been described in previous numbers of the *Publications of the Astronomical Society of the Pacific.*

Work with the spectroheliograph.—A temporary spectroheliograph, built for use with the Snow telescope pending the construction of the 5-foot spectroheliograph, gave excellent results during the summer of 1905. The new 5-foot spectroheliograph was completed in our instrument-shop and set up on Mt. Wilson in October. A description of this instrument has been published in *Contributions from the Solar Observatory,* No. 7, (*Astrophysical Journal,* January, 1906). Its principal advantages over the Rumford spectroheliograph are the larger aperture of the collimating and camera objectives, obviating loss of light at the Sun's limb; the possibility of photographing the entire disk with high dispersion; the ease of attaching slits of different curvatures; the possibility of using from one to four prisms, and either one or two mirrors in the optical train; the wide range of speed afforded by the driving mechanism; the elimination of the danger of distortion arising from imperfect synchronism in the motion of solar image and plate; and the ease of manipulation due to the general design and the improvement of details.

The new spectroheliograph has been in regular use since October 10th. Photographs of the Sun taken daily include H_1 plates, H_2 plates, and hydrogen plates. Photographs of

the prominences are also taken regularly when circumstances permit. During the broken weather of the rainy season, when the conditions are less favorable than in the summer months, the daily series is necessarily interrupted. At present experiments are in progress with high dispersion, using four prisms in the optical train. In certain classes of work the advantages of such high dispersion are very considerable, and it can soon be determined what systematic work in photographing the Sun with the dark lines can be undertaken to advantage with this instrument. It has been found that two prisms suffice to give good photographs of the hydrogen flocculi, on account of the high dispersion of the prisms employed and the considerable focal length of the spectroheliograph. Good photographs of the iron flocculi made with the line λ4045 are also taken frequently with the same dispersion.

The hydrogen photographs are of special interest, as they are the first to show the dark hydrogen flocculi over the entire disk of the Sun. In photographs made with the Rumford spectroheliograph the hydrogen flocculi are shown only in comparatively narrow zones. Several new phenomena of considerable interest have been brought out in the recent work. It has been ascertained that sun-spots on hydrogen plates are frequently surrounded, wholly or partially, by a narrow ring of bright hydrogen flocculi, lying just outside of the penumbra. Since ordinary hydrogen flocculi are dark, such bright rings are likely to prove of significance when systematically studied. They seem to have no counterpart on the photographs of calcium flocculi. Very dark hydrogen flocculi, found in only one or two instances on the Rumford spectroheliograph plates, are very common on the Mt. Wilson photographs. These flocculi, which are much darker than the ordinary hydrogen flocculi, have been long and narrow in form in all cases hitherto encountered. Photographs of the *IIδ* and *IIε* lines show that they are much strengthened and widened in these flocculi. A very significant fact, which confirms the view we have held regarding the nature of these objects, is the widening and strengthening of the H_3 and K_3 lines at the same points on the Sun. In a paper on the Rumford spectroheliograph (*Publications of the Yerkes Observatory*, Vol. III, No. 1), an

illustration was given of a *dark* calcium flocculus corresponding with one of these very dark hydrogen flocculi. The spectrum of such objects had not then been photographed, but there seemed to be no doubt that this particular form of hydrogen flocculus, at least, must lie at the H_3 level. This supposition is now confirmed.

The construction of the 30-foot spectroheliograph has been greatly delayed on account of the difficulty of obtaining suitable prisms of the large aperture required. It has now been found necessary to experiment with a new form of prism, which will be built up of a series of horizontal slabs, made from telescope disks of a single melting. There is reason to believe that on account of the ease of annealing these thin plates, prisms can be constructed in this way which will give better results than large prisms of a single block of glass. There will of course be a small loss of light, due to the manner of building up the prisms, but this should not be at all serious.

Spectra of sun-spots and flocculi.—The widened lines in the spectra of sun-spots have been successfully photographed in the third and fourth order spectra of a powerful Littrow spectrograph, having a combined collimator and camera lens of eighteen feet focal length. The widened lines are well shown in these photographs,, as well as the fainter lines, first found by YOUNG'S visual observations to constitute the general band of absorption in spot-spectra. The results and conclusions derived from a study of the lines affected in the photographs are given in *Contributions from the Solar Observatory,* No. 5, (*Astrophysical Journal,* January, 1906). A summary of this paper appeared in a recent number of the *Publications of the Astronomical Society of the Pacific.*

Mr. ADAMS has made a special study of the H and K lines and the motion of the calcium vapor in the flocculi. The measures of H_3 and K_3 show a general tendency to a displacement of this line toward the violet, which would correspond with an ascending motion of the high-level calcium vapor. Further measures will be required, however, before final conclusions can be drawn. H_2 and K_2 also show a displacement toward the violet. The detailed results may be found in *Con-*

tributions from the Solar Observatory, No. 6, (*Astrophysical Journal,* January, 1906).

Stellar Spectroscopy.—One of the principal objects of the Solar Observatory is to secure photographs of the spectra of certain bright stars with a high-dispersion spectrograph, on a scale comparable with that of ROWLAND'S photographs of the solar spectrum. The spectrograph used with the Snow telescope has collimating and camera lenses of 5 inches aperture and 13 feet focal length, mounted rigidly, with the slit, grating or prism train, and plate-holder, on a single massive stone pier. With the aid of a large plane grating, for the use of which we are indebted to the kindness of Professor AMES of Johns Hopkins University, the blue region of the first-order spectrum of *Arcturus* was photographed, but an exposure of fourteen hours on three successive nights was necessary. During this time the grating was automatically maintained at a constant temperature. On account of the long exposures required, it was thought advisable to experiment with prisms in place of the grating. Two of the large prisms of 63° angle (Jena glass 0.102), belonging to the 5-foot spectroheliograph, were accordingly used with a single mirror in place of the grating. Although the prisms were not large enough to receive more than one half of the light from the collimator lens, the resulting photographs were made with much less exposure time than was required in the case of the grating, while at the same time the linear dispersion is also considerably greater with the prisms. If the plan already mentioned, of constructing prisms of comparatively thin horizontal slabs, gives satisfactory results, it is probable that prisms, instead of a grating, will be employed in the high-dispersion stellar spectrograph which is to be used with the 5-foot reflecting telescope.

In a study of the less refrangible portion of the spectrum of *a Orionis*, which was photographed by ADAMS with the Snow telescope and the spectrograph just described, using a single prism, many of the lines which are widened in sun-spots, while absent or faint in the solar spectrum, have been found to be greatly strengthened. This tends to confirm conclusions reached in a study of stellar spectra of the third and fourth

types with the 40-inch Yerkes telescope (*Publications of the Yerkes Observatory,* Vol. II.).

Spectroscopic laboratory.—The spectroscopic laboratory on Mt. Wilson has recently been completed and investigations have been undertaken by Mr. GALE and myself on the behavior of the lines of titanium, iron, and other substances, which are widened in sun-spots, in a magnetic field, under varying self-induction, etc. The equipment of the laboratory, which has been specially designed for work of this nature, includes a powerful Du Bois magnet for the Zeeman effect, apparatus for producing arc and spark spectra at low and high pressures and in various gases, etc. The various light sources are arranged on the circumference of a circular pier, in such a way that light from any source can be reflected from a central plane mirror to a concave mirror which forms an image of the source on the slit of a long-focus Littrow spectrograph.

Computing division.—An addition to the office and instrument-shop building at Pasadena, providing space for computing offices, is under construction. A globe measuring-machine, for the rapid determination of the heliographic positions of sun-spots and flocculi, will soon be in use. In the first design the solar photograph, observed from a distance of 60 feet with a 4-inch telescope, was optically superposed on a silvered globe ruled with meridians and parallels one degree apart and mounted so that its axis could be placed parallel to the Sun's axis for the date of the photograph. This gave good measures, but another and more precise method of measurement suggested itself as the result of experiments with this instrument. In the modified apparatus settings will be made on the flocculi with cross-hairs exactly as would be done in a measuring-machine. The cross-hairs will then be observed in projection on the globe, which will be revolved in latitude and longitude until a point on its surface coincides with their intersection. The readings of two circles on the globe will then give the desired latitude and longitude. Other instruments provided for the Computing Division include a Zeiss stereocomparator, measuring-machines for spectra, and for rectangular co-ordinates, calculating machines, etc. It is hoped that this department of the observatory will soon be completely organized.

Smithsonian expedition.—For some years Secretary LANGLEY, of the Smithsonian Institution, had been planning to send an expedition to a mountain station for the purpose of measuring the solar constant, with special reference to its possible variability. At the invitation of the Solar Observatory, the expedition was sent to Mt. Wilson, in charge of Mr. C. G. ABBOT, and remained there from May until November, 1905. The conditions proved to be extremely satisfactory for the bolographic and pyrheliometric work, and Mr. ABBOT, who was assisted by Mr. INGERSOLL, secured a large number of observations, which are now in course of reduction. It is hoped that arrangements can be made to continue this work in future years.

Publications.—The publications of the Solar Observatory already issued include the following papers:

Contributions from the Solar Observatory:

No. 1. A Study of the Conditions for Solar Research at Mt. Wilson, California.
No. 2. The Solar Observatory of the Carnegie Institution of Washington.
No. 3. A Programme of Solar Research.
No. 4. Some Tests of the Snow Telescope.
No. 5. Photographic Observations of the Spectra of Sun-Spots.
No. 6. Some Notes on the H and K Lines and the Motion of the Calcium Vapor in the Sun.
No. 7. The Five-Foot Spectroheliograph of the Solar Observatory.

Report of Director of the Solar Observatory, Mt. Wilson, California (From *Year-Book* No. 4 of the Carnegie Institution of Washington).

Pasadena instrument-shop.—The work of instrument construction has gone on very successfully at the instrument-shop in Pasadena under the direction of Professor RITCHEY. The apparatus already constructed includes a spectroheliograph of 8 inches aperture and 5 feet focal length; a stellar spectrograph of 5 inches aperture and 13 feet focal length; a solar spectrograph (Littrow type) of 6 inches aperture and 18 feet focal length; a spectroheliograph temporarily used with the Snow telescope; a globe machine for measuring solar photographs; apparatus for the study of spark spectra in air and in

liquids; and many other miscellaneous instruments and apparatus used in conjunction with the Snow telescope and in the physical laboratory on Mt. Wilson. Much work has also been done on the mounting of the 5-foot reflector and in figuring concave and plane mirrors.

Five-Foot reflector.—The 5-foot mirror, which had been fine-ground by Professor RITCHEY at the Yerkes Observatory, was brought out to Pasadena last spring. It is now being figured, and the special precautions which Professor RITCHEY has taken promise to yield excellent results. The perfect equipment of the optical laboratory and the provisions made for maintaining the air at constant temperature and for excluding dust render the conditions for work extremely satisfactory. The heavy parts of the mounting have been practically completed by the Union Iron Works Company of San Francisco, and will soon be set up in a house erected for this purpose near the instrument-shop in Pasadena. The driving-clock and other parts of the mounting are under construction in our own shop, and the entire work of completing the instrument and of testing it in actual observation will be carried out before it is sent to Mt. Wilson. The steel building and dome which will contain the telescope are being constructed by the Union Iron Works Company.

GEORGE E. HALE, *Director.*

STUDENT'S OBSERVATORY, BERKELEY ASTRONOMICAL DEPARTMENT, UNIVERSITY OF CALIFORNIA.

This report covers the period from January 1 to December 31, 1905.

On July 1st Dr. A. F. GILLIHAN resigned his position as Assistant in Practical Astronomy to devote his time to private work. In recognition of his valuable services in connection with the designing and construction of the new equipment of the observatory he was given an appointment as honorary assistant. The position vacated by him was filled by the appointment of Mr. STURLA EINARSON, a graduate of the University of Minnesota.

Miss A. M. HOBE, who has been an assistant at the observatory for a number of years, resigned her position on December 1st to accept an appointment at the Lick Observa-

tory as Carnegie research assistant. Her work on the Watson asteroids is being continued by Mr. A. J. CHAMPREUX, Assistant in the Department of Mathematics.

The regular staff of the observatory consists of the Director, one instructor, Dr. RUSSELL TRACY CRAWFORD, and Mr. EINARSON, the assistant. The observatory is very fortunate in receiving a large amount of voluntary service from Dr. GILLIHAN, Dr. BURT L. NEWKIRK, Instructor of Mathematics and Watson Assistant in Astronomy, and Mr .A. J. CHAMPREUX.

The principal function of the observatory being that of instruction, the members of the department are able to devote themselves to astronomical investigations only under great pressure of time. Nevertheless, we have cause to be greatly gratified with the research work that has been accomplished.

The total number of enrollments in the department was two hundred and eighteen, and the number of different courses offered was fifteen. That the members of the department are pressed for time in their own investigations is apparent from the fact that practically all of the instruction is given by the Director and one instructor, the time of the only assistant being absorbed by observatory duties.

The only important additions to the equipment of the observatory are the camera-boxes for the five- and six-inch photographic lenses which have been completed. A few details affecting the convenience of manipulation of the instrument remain to be provided for. A preliminary measurement and reduction, by Dr. NEWKIRK, of a plate made with the six-inch lens (equivalent focal length 32″) indicates that a position of a well-defined object can be obtained from the measurement of a plate made with this instrument with an accuracy of about a second of arc.

Instruction is given chiefly to three classes of students,—viz., to those who elect the study of astronomy for culture purposes, to those who take up practical astronomy as a part of the engineering curriculum, and to a select few who desire a thorough training for the profession, either as practical or theoretical astronomers, astrophysicists, or geodesists.

There are now not less than five graduate students in the University who are preparing for the degree of Doctor of

Philosophy in Astronomy. Three of these hold fellowships in the Lick Observatory, and spend one semester each year in graduate work at Berkeley. One holds a position as Carnegie Research Assistant in the Lick Observatory. Two of the five are specializing in astrophysics, the other three in celestial mechanics. A thorough training in practical astronomy is offered both at the Lick and the Students' observatories.

The principal work of research of the Director has been on the improvement of the methods for computing orbits of comets, asteroids, and satellites. The theoretical results of these investigations are as yet unpublished, but frequent practical applications have been printed during the year in the *Lick Observatory Bulletin* by Dr. CRAWFORD and graduate students who take an active part in these investigations. The new results include an adaptation of the short method to the direct computation of a parabola for comets and of a circular orbit for asteroids, and other modifications to meet special conditions. The new parabolic method has been applied to each of the three new comets of the year. For Comet *a* 1905 two orbits were computed from a short and a long arc by Dr. CRAWFORD and Mr. MADDRILL. They announced the ellipticity of the orbit soon after discovery. For Comets *b* and *c*, two orbits each from a short and long arc were derived by Dr. CRAWFORD and Mr. CHAMPREUX. Comet *b* also appears to be periodic. An extension of the short method was derived from the solution of an osculating orbit of a comet, asteroid, or satellite in cases where these bodies are subjected to large perturbations during the period over which the observations extend. The new method permits of the determination of an osculating orbit from geocentric observations of a material point moving under the attraction of three or more bodies. An application of this method has been made to the seventh satellite of *Jupiter* by Dr. CRAWFORD and Mr. CHAMPREUX. The results are published on another page.

Considerable progress has been made on the perturbations and tables of the Watson asteroids. The chief assistants during the year in this work were Dr. NEWKIRK and Miss HOBE. In addition some fifteen students were engaged at various

times as piece-workers. The condition of the work of the twenty-two asteroids is as follows:—

For twelve planets the computations are practically completed, and the results will be published by the National Academy of Sciences as soon as the manuscript is finished. These results include the perturbations of the first order by *Jupiter,* tables from the year of discovery to 1930, a comparison of theory with observation for all available oppositions, and a final correction of the preliminary mean elements. It is proposed to publish the tables in advance of the details of the investigations. These twelve planets are (93) *Minerva,* (101) *Helena,* (103) *Hera,* (105) *Artemis,* (115) *Thyra,* (119) *Althaea,* (128) *Nemesis,* (133) *Cyrene,* (139) *Juewa,* (161) *Athor,* (174) *Phaedra, and* (179) *Klytaemnestra.* In the cases of (93), (101), (103), and (119) our work is based in part on previous investigations by EICHELBERGER and RITTER.

For three asteroids the perturbations have been developed and a preliminary correction of the elements made. These are (104) *Klymene,* (121) *Hermoine,* and (150) *Nuwa.*

Three other asteroids, (106) *Dione,* (168) *Sibylla,* and (175) *Andromache,* belong to the group ½, and special tables have been computed for this group after BOHLIN. Similar tables have been published by v. ZEIPEL. Certain discrepancies between our tables and those of v. ZEIPEL require further investigation. Two asteroids, (94) *Aurora* and (100) *Hekate,* were not originally included in our list, it being supposed that they had been taken up elsewhere. The development of their perturbations is under way. The computations were commenced last year by Dr. NEWKIRK and Miss HOBE, and are being concluded by Dr. CRAWFORD and Mr. CHAMPREUX.

For one asteroid, (79) *Eurynome,* perturbations have been computed by BECKER and tables by EICHELBERGER. A comparison between theory and observations and the correction of the elements remains to be made.

The last of the twenty-two, (132) *Aethra,* is lost. It was strongly disturbed during the discovery opposition. Miss HOBE has undertaken to trace it by applying the new method referred to above for determining osculating elements for an

asteroid, by taking immediate account of other attracting bodies besides the Sun. Hitherto not even special perturbations of this planet have been taken account of.

Dr. CRAWFORD has continued in his investigation of the constant of refraction. His first investigation was made in the year 1899, and resulted in the discovery that this so-called constant is a function of the zenith-distance. It was based on a series of observations made with the Repsold meridian-circle of the Lick Observatory during the summer months. The result of this investigation was

$$\triangle \log \mu = +0.000101 \quad (56^{\circ}.6 - z)$$

An independent investigation of a series of observations made during the winter months gives

$$\triangle \log \mu = +0.000117 \quad (59^{\circ}.3 - z)$$

The two results are entirely independent of each other, and are based on different star-lists. The most probable average result is $\triangle \log \mu = +0.000108 \quad (58^{\circ} - z)$

by which amount the Pulkova tables should be corrected.

Dr. NEWKIRK has made a thorough examination of the Repsold measuring apparatus after the method employed by GILL. The investigation includes an examination of the scales, of the micrometers, of the straightness of the cylinder which determines the Y axis and of the bar which determines the X axis, of the perpendicularity of these two, and tables of corrections.

Dr. NEWKIRK has also constructed extensive tables for the reduction of photographic measures on the basis of TURNER'S formulæ. The tables are to facilitate the transformation from standard rectangular co-ordinates to differences of right ascension and declination, with the converse transformation, and the computation of corrections for refraction, including terms higher than the first order in the measured co-ordinates. They are applicable in the reduction of measures of objects whose right ascension differs from that of the center of the plate by ten degrees or less, and whose declination differs from that of the center of the plate by five degrees or less, no matter what the declination of the center of the plate may be.

As in the past, the students of the University have enjoyed occasional lectures by members of the Lick Observatory and

others. The department has participated in the regular summer school of the University, a general and a practical course being offered by Dr. CRAWFORD.

The observatory has continued its meteorological and seismographic observations, the former being published monthly.

A. O. LEUSCHNER.

BERKELEY ASTRONOMICAL DEPARTMENT, March 24, 1906.

GENERAL NOTES.

The Carnegie Institution.—The report of President WOODWARD of the Carnegie Institution for the fiscal year ending October 31, 1905, was reprinted in *Science* of January 26th. Of the $435,000 appropriated for works of investigation, it is worth noting that $168,000, or 38 per cent of the whole, was apportioned to astronomical researches. Most of this was for the establishment and equipment of the Solar Observatory on Mt. Wilson.

A portion of the report is given up by President WOODWARD to a discussion of "large *versus* small projects." He seems to have decided leanings toward the former, and it is noticed that an astronomical observatory in the southern hemisphere is one of the large projects now under contemplation.

The Harvard Five-Foot Reflector.—Popular Astronomy for March contains an article, from the Chicago *Record-Herald,* giving a description of the mounting at Harvard College Observatory of the 60-inch reflecting telescope recently purchased from the estate of Dr. COMMON, of England. Many new problems have been encountered in mounting such a large mirror,—it weighs nearly a ton,—and the results to be obtained with it will be awaited with interest. The tube which contains the mirror is attached by means of a fork to the upper end of a polar axis. This latter is an immense steel cylindrical float, 18 feet long and 7 feet 8 inches in diameter, supported on pivots in a concrete tank, and so ballasted that it will hang at the proper angle when the tank is filled with water. Nearly the entire weight of the telescope and the axis may thus be thrown onto the water.

The eye-piece of the telescope is to be located permanently in the second story of a building immediately adjacent to, and presumably north of, the tank, and the rays of light are to be brought to it through the use of a system of auxiliary mirrors, the idea being similar to that employed in the equatorial Coudé. "The idea of supporting the polar axis in a tank of water, as first put into effect and perhaps originated by Dr. COMMON, is an especially practical one, whose simplicity and

economy in mounting a large instrument are at once apparent. But a great advance over the crude hand machinery for moving and guiding the telescope in its former mounting is being made at Cambridge. Through inventions and devices, the result of much thought and experiment on the part of Mr. GERRISH, the telescope is to be controlled and operated entirely by electricity. Small switches located at the desk in the observing-room will control motors and clutches by means of which the telescope can be swung at various speeds. A small motor, synchronized by an accurate clock, will give a uniform motion for following, while dials and indicators, also in the observing-room, will show at a glance the exact position of the telescope and the motion which is being imparted to it. Thus, while sitting comfortably at a desk in a warm room, unexposed to the weather, the observer can carry on his investigations on the coldest winter night as easily as on the pleasantest summer evening."

This last statement is of course theoretically true, but those who have had experience with large telescopes will have some doubts about the quality of the "seeing" in these cold winter nights, especially as the observing-room appears, from the picture given in *Popular Astronomy*, to be heated by means of a stove. Much was expected from the equatorial Coudé when the idea of observing in a warm room was first put into practical form, but as a matter of fact the instrument has produced but few results, and that is the real test of any instrument, although failure to produce results cannot always be placed upon the instrument, as has been amply demonstrated in at least one instance during recent years. It is sincerely to be hoped that Professor PICKERING and his coworkers will be able to overcome all difficulties and attain abundant success in carrying out their plans for this immense telescope. S. D. T.

Double Variable Stars.—The following very interesting note by Professor S. I. BAILEY has been taken from *Science* for March 16, 1906:—

"Two interesting cases have recently been discovered by Mrs. FLEMING at the Harvard Observatory, of double stars, both of whose components are variable. That two variable

stars should be close together, where variables occur in large numbers, as in the dense globular clusters, or to a less degree in the Magellanic clouds, would not be especially surprising. Even here, however, as a matter of fact, very few really close doubles are found. In the sky as a whole, away from such special regions, the number of known variables in the 40,000 square degrees of the sky is not much more than 600, or one in 67 square degrees. The chance, therefore, that two of them should come within a few seconds of arc of each other, unless there is some physical connection between them, is extremely small.

"The first double-variable consists of the well-known variable star *S Lupi* and a close companion, distant only 13", so close indeed that it may often have been mistaken for *S Lupi* itself, especially when it was bright and *S Lupi* faint. *S Lupi* has a period of 346 days, and varies in light about three and a half magnitudes, between 9.6 and 13.1. The close companion varies between 10.4 and 12.8, and its period appears to be irregular.

"Another variable pair has just been announced. The components are 40" apart. The first component varies between the magnitudes 10.0 and 10.6, and the second between 10.0 and 12.4. It will be of the greatest interest to determine whether there is any relation between the light-changes of the components, but this has not yet been possible.

"It is well known to astronomers that Mrs. FLEMING has discovered nearly two hundred variable stars by examination of photographic spectra, made with an objective prism, in connection with the work of the Henry Draper Memorial. By discovering that the spectra of long-period variables usually contain the bright lines due to hydrogen, she has been able to 'pick up' large numbers of variables of this class while engaged in other spectroscopic studies. It would have been quite impossible for a single observer, or perhaps for half a dozen, by visual methods, to find such a number in a lifetime. The results illustrate the power of photographic methods when the correct interpretation has been found. In this, as in some other lines of astronomical discovery, it would be almost a waste of time for an observer, unless for purposes

of recreation or amusement, to carry on the investigation visually. He would succeed about as well as a person who should attempt to race on foot with a fifty-horse-power automobile. This seems really a pity, as there is undoubtedly a greater charm, at least to the outsider, in the older methods. An observer, sitting at a desk with photographs about him, in a pleasant room in broad daylight, appeals to the imagination much less than the old-time astronomer, who was supposed to sit through the long cold night with his eye glued to his telescope. However, there are many fields in which the visual observer still has the advantage."

No. 4058 of the *Astronomische Nachrichten* contains a request by Herr BERBERICH, the newly appointed editor of the *Astronomicher Jahresbericht*, requesting that new publications be sent for review to his address, Berlin, Tempelhof, Schönburgstrasse 2.

A. N. No. 4061 contains a catalogue of thirty-nine newly discovered variable stars whose variability is regarded by the commission of the Astronomische Gesellschaft as established.

A. N. No. 4065: From the observatory at Moscow comes a report of the employment of photography in the measurement of double stars. A lens of 380^{mm} (15 inches) aperture and 6^{m} (20 feet) focal length was employed. Images of the double star were impressed upon the plate by exposures of from $1^{s}.30$ to $1^{s}.70$ duration. From 400 to 900 images were taken on a single plate. The orientation and scale value were determined by a trail, and by the distance between successive images made at measured intervals of time, the telescope being clamped and driving-clock stopped. Measures of the pair γ *Virginis* (dist. 5″.8) made on different plates agree to within about 0″.04. The pair ξ *Ursae Majoris* (dist. 2″.6) was also measured. It does not seem unreasonable to suppose that photography may in the near future lend important aid in the measurement of the wider doubles.

The Franklin Bicentenary.—The two-hundredth anniversary of the birth of BENJAMIN FRANKLIN will be appropriately celebrated on April 17th to April 20th next by the American Philosophical Society, Philadelphia, of which Dr.

FRANKLIN was founder. Besides the presentation of papers on scientific subjects there will be addresses by Professor E. L. NICHOLS, Professor ERNEST RUTHERFORD, Dr. H. H. FURNESS, President CHARLES W. ELIOT, Hon. JOSEPH H. CHOATE, and Hon. ELIHU ROOT. W. W. CAMPBELL.

A New Observatory in Hamburg, Germany.—It is announced that the city of Hamburg has appropriated 895,000 marks for the construction and equipment of an observatory under the direction of Professor SCHORR. A visual refractor of considerable size, a large reflector, a photographic refractor, and a meridian-circle are said to be in mind as the principal instruments. W. W. CAMPBELL.

Double-Star Work at the Flower Observatory.—It was my privilege some time ago to call attention in these *Publications* (Vol. XIV, pp. 106-109) to Professor ERIC DOOLITTLE's excellent double-star work with the 18-inch telescope of the Flower Observatory. It was apparent from the first volume of his measures that Professor DOOLITTLE brought to his work enthusiasm and energy as well as good judgment and keen observing powers. Fresh evidence of all these qualities is to be found in the more recent volume,[1] which contains measures of 1,066 double and multiple stars. Seven hundred and thirty-three of these stars are from BURNHAM's catalogue, 109 from OTTO STRUVE's, 102 from WILHELM STRUVE's, and the rest miscellaneous. In selecting these stars, Professor DOOLITTLE chose especially the "pairs of which there are few or no recent measures," and included also many that are in rapid motion or that have given some evidence of change. These stars "have been measured on an average of about five nights each," and very few on less than three nights. The observational data are conveniently arranged and critical notes are appended to many of the stars.

The volume bears very favorable testimony to the powers of the telescope and observer and to the atmospheric conditions prevailing at the Flower Observatory; for while the majority of the pairs measured are moderately easy, having distances

[1] 'Measures of 1066 Double and Multiple Stars Made with the Eighteen-inch Refractor of the Flower Astronomical Observatory," by ERIC DOOLITTLE.—Publications of the University of Pennsylvania. Astronomical Series. vol. III, Part III. 1905.

of from 1″ to 10″, and a considerable percentage are wide, still fully one fourth of the whole number are separated by 1″ or less, many of these pairs are quite unequal in magnitude and more than fifty are closer than 0″.5. The closest pairs successfully measured are *κ Pegasi, δ Equulei, and β*883. Such stars require "good seeing" for satisfactory measures with the largest telescopes. It is interesting to note that Professor DOOLITTLE's measures of the more difficult pairs are affected by much larger accidental errors in distance than in position-angle. Many of the pairs under 1″ show a range in distance of from 0″.25 to 0″.35, while the extreme range in position-angle rarely amounts to a linear displacement of 0″.1, and does not in general exceed 0″.05.

In the section on "The Method of Observing," in his introduction, Professor DOOLITTLE refers to the suggestion made in my review of his previous volume, that better results are likely to be obtained by measuring the position-angle with a single wire instead of with two separated by a few seconds of arc. Professor DOOLITTLE has experimented with the two methods, and finds that in his own case the first setting is nearer the true one if two wires are used. This is directly contrary to my experience, and, as it is a matter of practical interest to observers, it may not be amiss to point out once more the precise agreements and differences between the two methods.

We agree in discarding the slow-motion tangent-screw in measuring position-angles, and also in moving the whole micrometer-box longitudinally, making the wires pass back and forth over the stars till satisfied of the correctness of the setting. We are both also careful to keep the line joining the eyes either parallel or perpendicular to the line between the stars while making our measures.

But there are two points of difference in our practice that seem to me important. Professor DOOLITTLE apparently clamps the circle after making his first approximate setting, then moves the wires back and forth over the stars, and, finding the setting unsatisfactory, unclamps, changes it slightly, and repeats the process. My method differs in that the circle is never clamped, but is rotated slightly by the proper pinion,

making the angle alternately larger and smaller than the true value *simultaneously* with the longitudinal motion of the wires. Both motions are continued until a satisfactory setting is reached, the aim being to effect a direct bisection of the two star-images, not to get a line estimated to be parallel to their center line.

The other difference lies in the use of one wire instead of two in making our settings. In Volume V of the *Publications Lick Observatory* (p. 13) Professor HUSSEY, speaking of his measures of the OΣ stars, says: "All the settings for the determination of the position-angles have been made with a single wire, . . the other wire being placed so far from it as not to cause inconvenience or bias by its presence." I follow the same plan. We both find the close proximity of the second wire at least an inconvenience, especially in the case of close and unequal pairs, whereas Professor DOOLITTLE regards it as a distinct advantage.

Probably some physiological explanation must be sought for this fact as for the fact that some observers find it easier to make an accurate setting when the line between the eyes is placed perpendicularly to the line joining the stars than when it is placed parallel. R. G. AITKEN.

March 23, 1906.

Untersuchungen an den Spektren der helleren Gasnebel, von J. SCHEINER and J. WILSING.—This interesting paper of sixty pages forms a part of volume fifteen of the *Publications* of the Astrophysical Observatory at Potsdam. It treats of a subject which has received comparatively little attention since the classic work of Professor KEELER on the spectra of nebulæ (*Publ. L. O.*, Vol III, p. 165).

The lines of the present investigation follow closely those of KEELER in his determination of the radial velocities of fifteen of the bright nebulæ with the spectroscope of the Lick Observatory. Professors SCHEINER and WILSING have selected nine of the brighter nebulæ examined by him for their researches, the others being omitted on account of their low altitude at the latitude of Potsdam. The following is the list of nebulæ observed by them:—

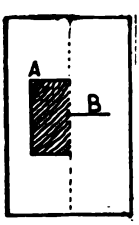
G. C. 4390 N. G. C. 7027 G. C. 4234 G. C. 4373
G. C. 4964 N. G. C. 6790 *Orion* (Tr.) G. C. 4514
N. G. C. 6891

A visual spectroscope mounted upon the Potsdam refractor was so designed that it could be used with slight changes for either of the following pieces of work which form the subject mater of the present article:—

I. A determination of the relative intensities of the principal lines in the spectra of the above nebulæ.

II. Measures of their velocities in the line of sight.

I. Relative intensities: For the investigation of the relative intensities of the three principal nebular lines the spectroscope was furnished with a 60° prism of fairly strong dispersion. A Zöllner photometer was so mounted on the spectroscope that the light from its lamp was thrown by a total reflection prism through one end of the slit and formed in the view telescope a spectrum alongside of that of the nebula examined. In the focal plane of the observing telescope a diaphragm (see figure) was placed carrying two apertures, one of which (A) is large enough to admit the three nebular lines. The other slit (B), which falls upon the spectrum of the artificial light, is of the same width and length as the nebular line. In this way the color of the comparison light can be made exactly the same as that of the nebular line, a very important condition to be fulfilled in photometric work of this nature. As a source of light for comparison an incandescent lamp was used whose intensity was found to remain fairly constant for short intervals of time. However, to guard against any change in the lamp, it was compared at the beginning and end of each series of observations with a benzene lamp (of SCHEINER'S design).



The method of observation was as follows: First, a comparison of the lamp with the benzene standard; then the slit B was shifted until it was in line with the principal nebular line, and the reading of the intensity circle of the photometer obtained, which rendered the intensity of B the same as that of the nebular line. Observations were made of the second and third nebular lines in a similar manner, then again of the

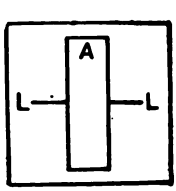
first line. Finally, a comparison of the lamp and standard was made.

Tables of the measures made by each observer, and the relative intensities of the second and third nebular lines referred to the principal line deduced therefrom, are given in full. Their observations confirm those of KEELER,—namely, that the relative brightness of the first and second nebular lines is within the limits of error of observation the same for all nebulæ examined, but the ratio of the intensities of the first and third line varies greatly for the different nebulæ. The actual intensites obtained depend, however, upon the distribution of energy in the spectrum of the artificial source. A comparison of the lamp with the benzene standard was made in order to determine the constants for reducing the measures to an absolute scale.

A table is here given of the nebulæ arranged in the order of intensity of the first nebular line (reduced to the benzene lamp), the intensity of the first line in the brightest nebula being taken as equal to magnitude 1.00.

Nebula.	Intensity of First Nebular Line.
G. C. 4390	$1^m.00$
N. G. C. 7027	1 .87
G. C. 4234	2 .07
G. C. 4373	2 .31
G. C. 4964	2 .68
N. G. C. 6790	2 .73
Orion (Tr.)	3 .26
G. C. 4514	3 .47
N. G. C. 6891	3 .90

II. Radial velocities: For the purpose of determining the velocities in the line of sight of the above nebulæ, the 60° prism was replaced by a Rowland plane grating, 36×49mm ruled surface, and 14,438 lines to the inch. The third order of this grating was used in all measures. For setting on the lines a different arrangement was employed from the usual one. It evidently possesses so many merits that it is worthy of notice here. A diagram, furnished with an aperture (A) to admit the spectrum of the nebula, and the slit (LL), through which the light from the photometer lamp passes, is carried along by the screw of the micrometer. The slit LL is used as the measuring-line,



and has the distinct advantages that it can be made of the same color, width, and intensity as the nebular line to be measured.

For the present investigation no attempt was made to determine the wave-length of the nebular lines, since with their apparatus Hβ was too faint in many of the nebulæ to admit of its being measured with accuracy. The first line only has been used in their measures, and for its wave-length they have adopted, KEELER's value, λ 5007.05. The iron line, λ 5006.31, was used for the comparison lines, and all measures made with reference to it.

Full data of all measures and results with the mean error of each observer are given for the nine nebulæ. A comparison of their results with those of other observers is given in the following table:—

Nebula.	Wilsing and Scheiner.	Keeler.	Hartmann.	Wright.	Vogel and Eberhard.	Frost and Adams.
G. C. 4234	— 32	— 34	....	....	....	....
G. C. 4373	— 64	— 65	— 66	....	....	....
G. C. 4390	— 7	— 10	— 11	— 11	....	....
N. G. C. 6790	+ 40	+ 48	....	....	....	....
G. C. 4514	0	— 5	....	....	....	....
N. G. C. 6891	+ 40	+ 41	....	....	....	....
N. G. C. 7027	+ 17	+ 10	+ 5	+ 12	....	....
G. C. 4964	— 5	— 11	....	— 7	....	....
Orion	+ 15	+ 18	....	+ 16	+ 17	+ 18.5

They give as their mean error of observation $\pm$ 3.2^{km}, while that for KEELER's observations is about $\pm$ 3.9^{km}. It should be noticed, however, that the variations between their individual observations is much greater in general than in the corresponding observations of KEELER, the reason for which is found in the fact that his observations were made with a more powerful instrument and under more favorable conditions. The mean error has been made comparable with his by increasing the number of observations. Their results are in satisfactory agreement with those of KEELER and form a valuable confirmation of his work. J. H. MOORE.

The Sun's Heat.—Professor H. H. TURNER, in his lectures on astronomy to young people in London recently, gave them a demonstration of what the Sun's heat might be like by melt-

ing iron in a furnace before their eyes. This experiment he performed by the ignition of thermit, which, burning at a temperature of over 3,000 degrees, produced a heat which is about half that of the Sun; and, as an illustration, the flaming mass was a striking pendant to the examples of liquid-air submitted to the audience previously, as exemplifying the cold of the lunar night.—*From Daily Graphic.*

An Artificial Eclipse.—The last of the Christmas lectures which Professor H. H. TURNER has been delivering at the Royal Institution was perhaps the most fascinating of a fascinating series. Bit by bit the Savilian professor had lured his youthful audience on till he almost brought them to the point of making astronomical calculations for themselves; and the last two minutes of the closing hour was occupied by them in drawing a corona from the artificial one which was thrown on the screen. The corona, as the lecturer explained, was in many respects the be-all and end-all of a total eclipse of the Sun, from an astronomer's point of view, and the drawing which the Royal Institution's budding astronomers were asked to make (on squares of cardboard with a central black spot to mark the eclipsed Sun) were made under conditions as far as possible resembling those under which observers labored before photography was applied to the problem. Thus, for about five explanatory minutes, the shadow of the imitation Moon crept over the bright disk of the electric Sun on the screen, while Mr. HEATH made ready photographic plates, and Professor TURNER gave directions about the cœlostat. Then suddenly totality supervened. An image of the corona flashed out on the screen, and the director-in-chief of the eclipse observations began to count, one by one, the hundred and twenty seconds during which totality would last and the million-mile rays of the corona would be visible. As he counted the seconds a hundred hurried pencils scratched out in the faint light the idea of the corona which impressed itself on the retinas of two hundred young eyes. The last second was counted out; the last click of the photographic cœlostat was heard; the corona disappeared like a flash, and the rim of the bright Sun once again appeared on the screen. It was a magnificent object lesson, and the youthful audience could not have cheered

their astronomical guide, philosopher, and friend more heartily if he had provided them with a real eclipse. He had, at any rate, furnished them in his lecture with all the data by which they might prepare themselves to observe the English total solar eclipse which will occur some twenty-one years hence, and which for twenty-five seconds will show the corona to observers in Yorkshire, Lancashire, and North Wales. He explained the methods of calculating the times and paths of an eclipse; he described the many preparations made by an eclipse expedition; and as far as possible he enumerated the various problems connected with the corona. One of the curious facts connected with it appeared from the observations made of it during the eclipses of the last century to be that this great luminous radiation was greatest in extent at the Sun's equator at a period of minimum sun-spots. That, however, was an observation which needed much more confirmation. It was also necessary to find whether the corona changed its form quickly or not. This could only be ascertained correctly by photography. Some most beautiful photographs had been obtained of the corona at a previous eclipse by Mrs. MAUNDER; and Mr. and Mrs. MAUNDER on the occasion of last year's eclipse had gone to Labrador so as to photograph the corona at as large an interval of time as possible from the similar photographs taken as Assouan. But bad luck dogged the steps of these two observers and culminated in a cloudy eclipse day, so that the question of the rate of change of the corona was still unanswered. Other investigations which might answer the most important question—the nature of the coronal light—were those connected with its diminution of intensity as it receded from the Sun.. By an examination of the degree and extent of this diminution, an examination on which Professor TURNER is himself engaged, we might come to some conclusion as to whether the particles which gave the light were doing so by reflected light, or whether they were incandescent and were giving the light themselves.—*From Daily Graphic.*

Science for March 23d contains titles and synopses of forty-one papers upon astronomical subjects which were read at the meeting of the Astronomical and Astrophysical Society

of America, held in New York, December 28-30, 1905. The same number of *Science* contains also titles and synopses of eleven papers upon mathematical and astronomical subjects which were read before Section A of the American Association for the Advancement of Science, at the meeting held in New Orleans on December 30, 1905.

Minutes of the Special Meeting of the Board of Directors of the Astronomical Society of the Pacific, held in the Rooms of the Society, on Saturday, November 25, 1905, at 2 p. m.

Vice-President Leuschner presided. A quorum was present.

The purpose of the meeting being the Sixth Award of the Bruce Gold Medal, the letters received from the Directors of the six nominating Observatories were submitted by the Secretary. After a careful consideration of the recommendations contained in these letters, the selection of the Medalist was made by ballot, and the following certificate of bestowal was signed by all Directors present:—

San Francisco,
November 25, 1905.

Sixth Award of the Bruce Medal.

We, the undersigned Directors of the Astronomical Society of the Pacific, hereby certify, that, in accordance with the Statutes for the bestowal of the Bruce Medal, a special meeting of the Board of Directors was held this day, at two o'clock p. m., for the purpose of awarding the medal for the year 1906; and that, the provisions of the Statutes relating to its bestowal having been complied with, the medal was awarded to—

HERMANN CARL VOGEL,

for Distinguished Services to Astronomy, by the consenting votes of eleven Directors.

Signed: R. G. Aitken,* Chas. Burckhalter, W. W. Campbell,* Wm. H. Crocker,* Chas. S. Cushing, A. H. Babcock, Geo. E. Hale,* A. O. Leuschner, S. D. Townley,* Geo. C. Pardee,* F. R. Ziel.

(*By Proxy)

Adjourned.

In answer to a letter addressed to Professor Vogel, notifying him of the action taken by the Directors, the following letter of acceptance was received:—

[TRANSLATION]

Astrophysical Observatory,

Mr. F. R Ziel, Potsdam, January 20, 1906.

Secretary of the Astronomical Society of the Pacific, San Francisco.

In reply to your favor of the 1st inst., I beg to state that I greatly appreciate the bestowal upon me of the Bruce Medal by the Astronomical Society of the Pacific, and shall be much pleased to accept the medal. I request you to transmit to the Society my grateful thanks for the distinction conferred upon me.

With great esteem,

Professor Dr. H. C. Vogel.

Minutes of the Meeting of the Board of Directors, held in the Rooms of the Society, March 31, 1906, at 7:30 p. m.

President Townley presided. A quorum was present. The following members were duly elected:—

List of Members Elected March 31, 1906.

Mr. John R. Haake .....308 California St., S. F., Cal.
Shattuck Observatory.....Dartmouth College, Hanover, N. H.
Mr. Elliott Smith.....Lick Observatory, Mount Hamilton, Cal.

Adjourned.

Minutes of the Eighteenth Annual Meeting of the Astronomical Society of the Pacific, held in the Lecture Hall of the California Academy of Sciences, March 31, 1906, at 8 p. m.

The meeting was called to order by President Townley. A quorum was present. The minutes of the last meeting were approved.

The following papers were presented:

Address of the retiring President, Dr. S. D. Townley, in awarding the Bruce Medal to Professor Dr. Hermann Carl Vogel.

The Lick Observatory-Crocker Expeditions to observe the Total Solar Eclipse of August 30, 1905, by Professor C. D. Perrine.

Astronomical Observations in 1905, by Professor Torvald Köhl.

Planetary Phenomena for May and June, 1906, by Professor M. McNeill.

The Committee on nominations reported a list of names proposed for election as Directors, as follows: Messrs. R. G. Aitken, A. H. Babcock, Chas. Burckhalter, W. W. Campbell, Wm. H. Crocker, Chas S. Cushing, Geo. E. Hale, A. O. Leuschner, D. S. Richardson, A. B. Spreckels, F. R. Ziel.

For Committee on Publications: Messrs. R. G. Aitken (Chairman), S. D. Townley, B. L. Newkirk.

Messrs. von Geldern and Lietz were appointed as tellers. The polls were open from 8.15 to 9 p. m., and the persons above named were duly elected to serve for the ensuing year.

Report of the Committee on the Comet Medal, Submitted March 31, 1906.

Five unexpected comets were announced in the calendar year 1905.

Comet a 1905 was discovered at Nice, France, on March 26th, by Michel Giacobini.

Comet b 1905 was discovered at Geneva, Switzerland, on November 17th, by Emil Schaer.

Comet c 1905 was discovered at Nice, France, on December 6th, by Michel Giacobini.

Comets d and e 1905 were announced by V. M. Slipher and Percival Lowell respectively by means of a photograph taken at the Lowell Observatory, Flagstaff, Arizona, on November 29th. Announcement of Comet d reached the Pacific Coast on December 14th, and of Comet e on December 29th. These comets have not been observed visually, and the facts concerning them rest upon the single discovery photograph.

The Donohoe Comet-Medal of the Society has been awarded to the discoverers of comets a, b, and c. The rules governing the award of the medal do not make it applicable to comets d and e.

W. W. CAMPBELL,
CHAS. BURCKHALTER,
WM. H. CROCKER,
Comet-Medal Committee.

The Treasurer Submitted His Annual Report as follows:—

Annual Statement of the Receipts and expenditures of the Astronomical Society of the Pacific for the Fiscal Year ending March 31, 1906.

GENERAL FUND.

Receipts.

1905, March 26th. Cash Balance			$ 115 04
Received from dues for 1905 and previous years	$ 215 26		
Received from dues for 1906	559 14	$ 774 40	
Received from Life membership fee		50 00	
Received from sales of Publications		6 75	
Received from sales of Stationery		40	
Received from Life Membership Fund (interest)		71 40	
Received from John Dolbeer Fund (interest)		218 52	1,121·47
			$ 1,236 51
Less transfer to Life Membership Fund			50 00
			$ 1,186 51

Expenditures.

For Publications: printing Nos. 101 to 105	$ 455 65		
illustrations	86 96	$ 542 61	
Stationery and printing	90 37		
Reprints	41 25		
Postages	55 39		
Rent	180 00		
Salary Secretary-Treasurer	180 00		
Expressages	11 65		
Telephones	1 90		
Janitor	4 50		
Gas	50		
Insurance premiums	21 85		
Lantern at lecture	8 00		
Engrossing	4 25		
Taxes	2 48		
Rent safe desposit box	5 00		
Bank Exchanges	65	607 79	1,150 40
1906, March 31st. Cash Balance			$ 36 11

Bills receivable:

Dues outstanding:		
for 1905	$ 55 00	
for 1906	230 00	
	$ 285 00	
Publications sold	30 00	
	$ 315 00	

Bills payable:

Publications: printing No. 106	$ 306 45

LIFE MEMBERSHIP FUND.

1905. March 26th. Cash Balance	$ 1,903	95
Received from General Fund (fee)	50	00
Interest	71	40
	$ 2,025	35
Less transfer to General Fund (interest)	71	40
1906, March 31st. Cash Balance	$ 1,953	95

ALEXANDER MONTGOMERY LIBRARY FUND.

1905, March 26th. Cash Balance	$ 1,470	83
Interest	64	60
	$ 1,535	43
Less expenditures:		
Astronomical Journal, Nos. 1 and 4 of Vol. 1	1	56
1906, March 31st. Cash Balance	$ 1,533	87

DONOHOE COMET-MEDAL FUND.

1905, March 26th. Cash Balance	$ 747	55
Interest	26	87
	$ 774	42
Less engraving medals Nos. 48 to 52, and postage	7	85
1906, March 31st. Cash Balance	$ 766	57

BRUCE MEDAL FUND.

1905, March 26th. Cash Balance	$ 2,650	40
Interest	120	99
	$ 2,771	39
Less remittance to A. Dubois fils, Paris (sixth award)	102	35
1906, March 31st. Cash Balance	$ 2,669	04

JOHN DOLBEER FUND.

1905, March 26th. Cash Balance	$ 5,000	00
Interest	218	52
	$ 5,218	52
Less interest expended for Publications (see resolution, No. 105, page 207)	218	52
1906, March 31st. Cash Balance	$ 5,000	00

WILLIAM ALVORD FUND.

1905, December 20th. Cash received from Estate of William Alvord	$ 5,000	00

FUNDS.

Balances as follows:

General Fund:		
with Donohoe-Kelly Banking Co.....		$ 36 11
Life Membership Fund:		
with German Savings and Loan Society....	$ 953 95	
South Pacific Coast Railway Co., $1,000 Bond, No. 3,406	1,000 00	1,953 95
Alexander Montgomery Library Fund:		
with Security Savings Bank.....	$ 493 87	
Oakland Transit Consolidated, $1,000 Bond, No. 4,328	1,040 00	1,533 87
Donohoe Comet-Medal Fund:		
with San Francisco Savings Union.....		766 57
Bruce Medal Fund:		
with Mutual Savings Bank.....	$ 679 32	
Bay Counties Power Co., $1,000 Bond, No. 1,636	1,012 50	
The Edison Electric Co., $1,000 Bond, No. 168	977 22	2,669 04
John Dolbeer Fund:		
with Union Trust Co.....	$ 970 28	
South Pacific Coast Railway Co., $1,000 Bond, No. 3,407	1,000 00	
Oakland Transit Consolidated, $1,000 Bond, No. 4,329	1,040 00	
Bay Counties Power Co., $1,000 Bond, No. 1,637	1,012 50	
The Edison Electric Co., $1,000 Bond, No. 169	977 22	5,000 00
William Alvord Fund:		
with Humboldt Savings Bank.....	$ 2,500 00	
with Savings and Loan Society.....	2,500 00	5,000 00
		$16,959 54

San Francisco, March 31, 1906.

F. R. ZIEL, Treasurer.

Examined and found correct.

CHAS. S. CUSHING, }
FREMONT MORSE, } Auditing Committee.

The report was, on motion, accepted and filed.

After having read his address, President Townley introduced the lecturer of the evening, Professor Perrine, who gave an account of the three Eclipse Expeditions sent out by the Lick Observatory to observe the Eclipse of August 30, 1905, and showed a number of photographs of the stations, of the instruments used and of the results obtained by the photographic telescopes.

The following resolution was, on motion adopted:

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by said Board during the past fiscal year, are here, now, by this Society, approved and confirmed.

Adjourned.

Minutes of the Meeting of the Board of Directors, held in the Rooms of the Society, March 31, 1906, at 10 p. m.

The new Board of Directors was called to order by Mr. Burckhalter. A quorum was present. The minutes of the last meeting were approved.

The business in hand being the election of officers for the ensuing year, the following officers, having received a majority of the votes cast, were duly elected:—

President: Mr. Armin O. Leuschner.
First Vice-President: Mr. Chas. S. Cushing.
Second Vice-President: Mr. A. H. Babcock.
Third Vice-President: Mr. W. W. Campbell.
Secretaries: Messrs. R. G. Aitken and F. R. Ziel.
Treasurer: Mr. F. R. Ziel.

Committee on the Comet-Medal: Messrs. W. W. Campbell (ex officio), Chas. Burckhalter, C. D. Perrine.

Library Committee: Mr. von Geldern, Mr. Richardson, Mrs. Schild.

Mr. von Geldern was appointed Librarian.

The President was authorized to appoint the members of the Finance Committee, and made the following selections:

Finance Committee: Chas. S. Cushing (Chairman), Wm. H. Crocker, D. S. Richardson.

The Committee on Publication is composed of Messrs. R. G. Aitken (Chairman), S. D. Townley, B. L. Newkirk.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. A. O. Leuschner.....President
Mr. Chas. S. Cushing.....First Vice-President
Mr. A. H. Babcock.....Second Vice-President
Mr. W. W. Campbell.....Third Vice-President
Mr. R. G. Aitken
Mr. F. R. Ziel. } .....Secretaries
Mr. F. R. Ziel .....Treasurer

Board of Directors—Messrs. Aitken, Babcock, Burckhalter, Campbell, Crocker, Cushing, Hale, Leuschner, Richardson, Spreckels, Ziel.
Finance Committee—Messrs. Cushing, Crocker, Richardson.
Committee on Publication—Messrs. Aitken, Townley, Newkirk.
Library Committee—Mr. Von Geldern, Mr. Richardson, Mrs. Schild.
Committee on the Comet-Medal—Messrs. Campbell (ex-officio), Burckhalter, Perrine.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the Publications for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the Publications of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the Publications is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the Publications should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communictaed to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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COMMITTEE ON PUBLICATION.

ROBERT G. AITKEN, Mt. Hamilton, Cal.
SIDNEY D. TOWNLEY, Ukiah, Cal.
BURT L. NEWKIRK, Berkeley, Cal.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XVIII. SAN FRANCISCO, CALIFORNIA, JUNE 10, 1906. No. 108.

A STATEMENT BY THE PRESIDENT OF THE SOCIETY.

The first regular meeting of the society since the California earthquake of April 18th, and the subsequent conflagration in San Francisco, was held on the evening of June 9th. By courtesy of the president of the University of California, the members of the society were welcomed to a temporary home in the Students' Observatory at Berkeley. The former rooms of the society in the California Academy of Sciences Building in San Francisco, with a fine collection of photographs, and a splendid library, acquired by judicious purchase throughout the seventeen years of the society's existence and enriched by generous private donation and contribution from astronmical observatories and learned societies all over the world, were totally destroyed by the fire, which wiped out the business section of San Francisco and the greater part of the residence districts. The insurance of $2500, which the society carried on its belongings, in the Academy of Sciences Building, will suffice only for a partial restoration of its property. Among the more valuable sets of publications lost, are several which probably cannot be completely replaced. Nevertheless, the president and the directors are confident that an appeal to be issued to the leading astronomical observatories and societies as well as to authors, will soon give the society a new and valuable library.

Number 107, of the *Publications* was to be mailed on the day of the disaster, but the secretary was not permitted to cross the fire lines and thus the whole edition, with the exception of a single advance copy, was burned in the printing establishment. This number was immediately reprinted in Los Angeles and has since been distributed. The present number 108 has been unavoidably delayed, but from now on the *Publications* will continue to appear as though nothing had happened. By a wise provision of the first board of directors, a supply of the *Publications* has been regularly de-

posited at the Lick Observatory and has thus escaped destruction.

The Finance Committee reports that the permanent funds of the society, aggregating nearly $17,000, are intact, and the bequest of Morris Rieman, of Chicago, Illinois, amounting to $500.00 has just been received. The society's membership is scattered all over the globe and is as strong as ever. Thus, after all, the society has every reason to be thankful. A source of particular pleasure to every member of the society must be the fact that every astronomical observatory of the State, including the Lick Observatory and the Solar Observatory of the Carnegie Institution remained absolutely unharmed. At the Students' Observatory, which was nearest to the fault line, nothing was disturbed, not even a book dropped from the shelves.

The society has lost none of its enthusiasm and will continue to disseminate the results of research in the oldest and noblest of sciences, through lectures and publications, with ever increasing vigor and let it be hoped, effectiveness.

A. O. LEUSCHNER.

Berkeley, Cal., June 9, 1906.

NOTICE TO MEMBERS AND CORRESPONDENTS.

Until further notice all publications intended for the society, should be addressed to the library of the Astronomical Society of the Pacific (care of the Students' Observatory, Berkeley, California.) The business address of the society is 806 Franklin street, San Francisco, Cal., U. S. A., F. R. ZIEL, secretary.

Members of the society and others having extra copies of Nos. 1, 2, and 48, of the *Publications* are requested to forward them to the secretary at Mount Hamilton, for the completion of the sets, which have escaped destruction.

OBSERVATIONS OF DISTANT EARTHQUAKES[1].

By F. Omori.

The earthquake motion consists in general of several sets of vibrations, whose amplitude and period range within wide limits. We shall find it convenient to divide the motion into two classes: the *Sensible* or *Macro-Seismic,* namely that which can be felt as tremblings or shocks; and the *Insensible* or *Micro-Seismic,* namely that which cannot be felt. In the former, quick vibrations co-exist with slower ones, while in the latter quick vibrations are either absent or extremely minute. Some of the vibrations in the insensible motion are as large as, or even larger than, the vibration in small but sensible local earthquakes; they are insensible only because their period is very long and consequently their acceleration small; the lowest limit of the "intensity" or acceleration of the sensible motion being about 17^{mm} per second. The quick period and short length waves in the earthquake motion are dissipated, with the increase of the distance from the center of disturbance, more rapidly than the slow, and long waves; the result being that the motion due to a distant earthquake is simpler in character than that due to a near one, and is entirely micro-seismic or insensible. A "distant earthquake" may here be taken as denoting a seismic disturbance, whose epi-central distance from a given station is over some 2000^{km} or 1500 miles.

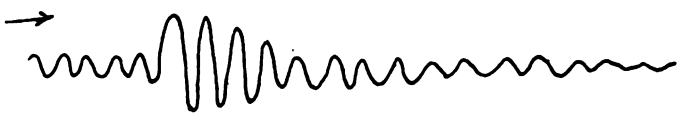
The Earth's crust being regarded as an elastic medium through which seismic waves are propagated, the investigation of these waves, of their mode of propagation, and their behavior under various circumstances form a very important branch of the physics of the Earth, and especially the observations of distant earthquakes lead to several interesting results, which may help the solution of some of the important problems relating to the condition of the Earth's interior. By means of modern seismographs, which are very sensitive, we can observe a great earthquake in any part of the world, the motion due to such a disturbance lasting generally from 1 to 5 hours.

NEAR EARTHQUAKES. For the sake of reference, I shall state briefly the character of an ordinary or sensible earthquake disturbance. Such a motion, as observed with a seismograph, begins always with vibrations of small amplitude and comparatively short period. These are known as the *preliminary tremors* and last from a few seconds to a few

[1]Read at the meeting of the Society, June 9, 1906.

minutes; next come those of large amplitude, constituting the principal and most active part; and finally the earthquake

DIAGRAMMATIC REPRESENTATION OF THE EARTHQUAKE MOTION



AB—Preliminary tremor. BC—Principal portion. CD—End portion.

ends with feeble movements, which may be called the *end portion.* When the origin of the disturbance is near to the observer, a rumbling sound like that of distant thunder, or a rushing sound like a blast of wind is heard just before the arrival of the tremblings of the ground. These sound phenomena, which are of frequent occurrence in a rocky district, but very rare at places situated in plains, are probably due to the rapid vibrations existing in the *preliminary tremor.* The well-known fact that some animals often show signs of disquietude just before an earthquake, is probably due to their having an acute feeling and being alarmed at the first movements of the preliminary tremor. The duration of the preliminary tremor does not depend on the magnitude of the earthquake, but is found to vary with radial distance. Thus if Y denote the duration of the preliminary tremors of an earthquake, at a place, whose distance from the origin of disturbance is X, we have the following empirical equation:

$$X^{km} = 7.27Y^{sec} + 38^{km}$$

which is to be used for values of X between 100 and 1000 km. This equation is very useful and enables us to estimate, from the diagram taken at any station by a sufficiently sensitive seismograph, the distance of the earthquake origin. Or, if the seismograph records be simultaneously taken at two or more stations, we can easily fix the approximate position of the origin. As an example, I refer to the excellent Ewing seismograph record* taken by DR. CAMPBELL at the Lick Observatory of the great earthquake of April 18th, last. According to that seismogram, the preliminary tremor lasted about 10 to 12 seconds, from which it may be inferred that the most central part of the great disturbance was at a distance of about 130^{km}, or some 80 to 90 miles, from Mount Hamilton.

*See illustration facing page 212.

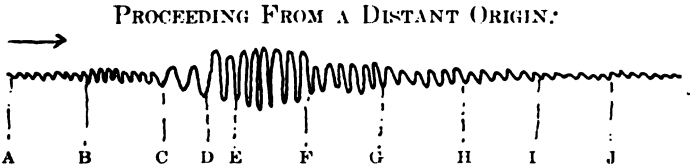
The duration of the strongest part in the principal portion in destructive earthquakes, which varies generally between 4 and 10 seconds, reaches, in case of extensive disturbance, some 30 seconds. From the Lick Observatory seismogram above mentioned, the duration of the principal portion in the recent great shaking seems to have been about 40 seconds.

In slight earthquakes, the movement of the ground is small, being a mere fraction of a tenth of an inch. When the motion reaches some one-half inch, the earthquake becomes strong and may cause slight damage. When, further, the motion reaches a few inches, the earthquake is destructive, and ordinary brick houses, chimneys, etc., will be considerably damaged. The motion in the strongly shaken parts of San Francisco in the recent earthquake, was probably 3 inches.

In ordinary cases, the vertical component of the earthquake motion is much smaller than the horizontal, being, even when very great, unable by itself to produce any great damage. In fact, with respect to the destructive power of the earthquake motion, the vertical component is only of secondary importance in comparison with the horizontal; in other words, the seismic damage to structures may, excepting the cases of sinking of foundations or collapsing of thin and weak vaults, be regarded as due to the horizontal motion.

DISTANT EARTHQUAKES. A careful examination of seismograms shows that the earthquake motion consists generally of several phases or sections, in each of which the period remains essentially constant, while the amplitude is also on the whole constant, except for the occurrence of maximum and minimum groups.

DIAGRAMMATIC REPRESENTATION OF THE EARTHQUAKE MOTION PROCEEDING FROM A DISTANT ORIGIN.



AB—1st preliminary tremors.
BC—2nd preliminary tremors.
CD—1st phase of the principal portion.
DE—2nd phase of the principal portion.
EF—3rd phase of the principal portion
FG—4th phase of the principal portion.
J—End portion.

The successive phases of the earthquake motion, illustrated in the figure, are as follows:

The *preliminary tremor*, which consists of vibrations of small amplitude and of comparatively short period, is divided into the earlier portion or the *first preliminary tremor*, and

the later portion or the *second preliminary tremor*. Commencement of the latter is marked by an increase of the amplitude, and, in many cases, also by the appearance of slow undulations.

The *principal portion* denotes the most active part of an earthquake which follows the preliminary tremors and consists of movements of larger amplitude. The earlier part of the principal portions is further subdivided into three successive stages as follows: (a) the *first phase*, consisting of a few very slow movements; (b) the *second phase*, consisting of slow movements, whose period is generally somewhat shorter than in the first phase; (c) the *third phase*, consisting of vibrations of a period much quicker than that in the preceding two phases. The third phase is followed by others of smaller amplitude. (FG, GH, etc.,) which may be termed respectively the fourth, fifth, sixth,. . .phases of the principal portion.

Lastly, the *end portion* denotes the feeble finishing part of earthquake motion, which follows the principal portion.

In earthquakes of near origin, the motion is, on account of the existence of quick vibrations of macro-seismic character, much more complex than in distant earthquakes, it being generally difficult to subdivide the principal portion into the different phases.

As in the case of near earthquakes, the *duration* of the preliminary tremors at a given place is found to depend on the distance of the origin; thus let X denote the actual distance between the epicenter and the observing place, and Y the total duration of the first and second preliminary tremors, then we have the following empirical relation:

$$X^{km} = 6.54\ Y^{sec} + 720^{km}$$

which has been deduced from the observation of different earthquakes, whose X varied between 2000 and 14,000^{km}. Again, if Y_1 denote the duration of the first preliminary tremor, X having the same signification as before, we get the following formula:

$$X^{km} = 17.1^{sec}\ Y_1 - 1360^{km}$$

Each of these equations may be used for determining at once the distance of an unknown earthquake from the record taken at any given place.

The time ($= T_0$) of occurrence at the origin of any distant earthquake may approximately be calculated, from the seismographical record, by the following empirical formula:

$$T_0 = T - 1{,}165\ Y_1$$

where Y_1 has the same meaning as before, and T denotes the time of earthquake occurrence observed at a given place.

PULSATORY OSCILLATIONS. Before going further, let me refer to a phenomenon called "pulsatory oscillations." These are small slow pulse-like movements which are not of the earthquake origin; the ground being more or less in a state of vibration even when there is no earthquake at all. In some pronounced storms of pulsatory oscillations, the motion is quite as large as in small earthquakes; the maximum amplitude in each component being sometimes nearly 0.2^{mm}. Again, the horizontal motion is, in general, much greater than the vertical, although, in some cases, the latter is very marked and nearly equal to the former. The pulsatory oscillations, which may last for several days, do not indicate any succession of different phases as in the case of a great distant earthquake, although they are subject to alterations of maximum and minimum groups. As the period of pulsatory oscillations varies little, and remains constant for several successive hours, it may be supposed that these movements represent the proper vibrations of certain portions of the Earth's crust, such for instance as the plain of Musashi on which Tokio is situated. In fact, the different portions of the Earth's crust are continually executing greater or less movements, and the period of some of these vibrations ought to be determinable in each case from the geotectonic circumstances of the locality.

A careful examination of the horizontal pendulum diagrams obtained in Tokio shows that the pulsatory oscillations consist, in most cases essentially of vibrations with a period of about 4 seconds, more or less mixed up with those of a period of about 8 seconds. The vibrations of 4 seconds period occur very frequently, but cases are not wanting, where the vibrations of the 8 seconds period predominate almost exclusively. Again, there are sometimes cases in which the two kinds of vibrations occur in different parts of one and the same diagram. The average values of the periods of these two series of vibrations are respectively 4.4 sec. ($= Q_1$) and 8.0 sec. ($= Q_2$). We may perhaps assume that the 8 seconds period vibration constitutes the fundamental oscillation proper to the Tokio plain, the 4 seconds period being one of its harmonics.

The average period of the principal pulsatory oscillations at Osaka, Formosa, Göttingen, and some other places, is either nearly 4 seconds or nearly 8 seconds. It may be that the period (or periods) of the pulsatory oscillations is approximately constant all over the world.

Pulsatory oscillations generally accompany a cyclone; the effect of a great atmospheric depression being already sensible at a distance of some thousand kilometers. In a few cases, however, pronounced storms of pulsatory oscillations occurred on days when very quiet weather prevailed all over Japan.

In Tokio, earthquakes occur rather rarely, while pulsatory oscillations are going on actively. On the other hand, there are often local shocks when these oscillations come to a state of minimum activity.

PERIODS OF EARTHQUAKE VIBRATIONS. The predominating periods in the different phases of the distant earthquake motion observed at *Hitotsubashi* (Tokio) were as follows; those very frequently occurring being given in black letters.

	sec.	sec.	sec.	
1st preliminary tremors.....	1.04	**4.6**	**8.7**	
2nd " "	**8.5**	14.8		
3rd section	22.9	27.6		
4th "	13.6	17.8	22.3	25.9
5th "	**9.3**	13.6		
Tail	**9.6**	16.0		

It will be observed that the two periods of about 4.5 and 8.5 sec. occur most frequently in the preliminary tremors; this being also the case with the observations at Hongo (University.)

Thus there are, in the first and second preliminary tremors, two predominating periods, which may be denoted by P_1 and P_2 and whose mean values are

$$P_1 = 4.6 \text{ sec.}, \quad P_2 = 8.3 \text{ sec.}$$

Now these are practically identical respectively with the two periods, $Q_1 = 4.4$ sec. and $Q_2 = 8.0$ sec., found for the pulsatory oscillation in Tokio. Moreover the periods P_1 and P_2 do not depend on the distance of an epicenter from the observing station, or on the nature of the disturbance at the seismic origin, but are characteristic of the region about Tokio. A similar conclusion probably holds good also for the periods in other stages of the earthquake motion. The conclusion is that the principal vibrations in the preliminary tremors of distant earthquakes and pulsatory oscillations are identical phenomena. The existence of P_1 and P_2 vibrations in the principal portion of the distant earthquake motion has been confirmed by the recent earthquake observations made in Formosa, and also by the observations in Tokio of the great Indian earthquake of April 4th, 1905.

We may probably explain the existence of the preliminary tremors somewhat as follows: The waves of the preliminary tremors are transmitted along a deep layer of the Earth's crust with a velocity of some 14^{km} of which I shall speak presently, and communicate a sort of stress to the superincumbent surface layer of the Earth's crust in the region about the observing station; the latter being, in consequence, thrown into its own proper vibrations. In fact, the preliminary tremors seem to be nothing else than the pulsatory oscillations, caused by the waves transmitted along a deep layer of the Earth's crust from the origin of earthquakes.

Taking the observations of great distant earthquakes, predominating periods in the different phases of the motion were found to be as follows:

	sec.	sec.	sec.
1st preliminary tremors	4.1	7.8	13.9
2nd " "	4.8	8.2	15.0
Principal Portion, 1st phase	36.1		
" " 2nd phase	27.5	33.7	
" " 3rd phase	20.4	24.0	
" " 4th phase	11.7	14.9	
" " 5th phase	14.3		
" " 6th phase	14.5		
End Portion	9.9	14.3	19.8

The durations of the different phases of the earthquake motion are roughly equal to one another; the first and second phases of the principal portion being taken together.

The amplitude of motion is smallest in the first preliminary tremors, and greatest in the second and third phases of the principal portion.

The mean relative maximum amplitudes in the first and second preliminary tremors and in the successive phases of the principal portion were as follows:

	mm.
First preliminary tremor	100
Second preliminary tremor	560
First phase, principal portion	550
Second phase, principal portion	1820
Third phase, principal portion	1220
Fourth phase, principal portion	840
Fifth phase, principal portion	560
Sixth phase, principal portion	430

THE VELOCITIES OF PROPAGATION OF THE VIBRATIONS. In calculating the velocities of propagation of distant earthquake waves, it makes a great difference according as we suppose the waves to be propagated along the chord of the Earth joining the origin to the observing station or

parallel to the surface. Calculated on this latter supposition, which seems to be more probable, the velocities of the different waves of the earthquake motion come out approximately the same, irrespective of the arcual distances, those cases, in which epicentral distance is small, say some 30 degrees, being excluded. On the chord supposition, the corresponding velocities come out quite different, according to the distances.

If we denote by V_1, V_2, V_3, V_4, V_5, V_6, V_7, and V_8, the velocities of propagation (supposed parallel to the Earth's surface) of the waves at the commencement of the successive phases of the earthquake motion, their mean values are as follows:

V_1 = 13.7 km per sec.	V_5 = 3.3 km per sec.
V_2 = 7.2 km per sec.	V_6 = 2.8 km per sec.
V_3 = 4.6 km per sec.	V_7 = 2.4 km per sec.
*V_4 = —— km per sec.	V_8 = 2.1 km per sec.

Now the velocity of propagation of the vibrations at the commencement of the principal portion of a *near* earthquake is 3.3^{km} (or 2 miles) per second, which is the same as V'_5 above. Hence it is evident that the vibrations in the third phase of the principal portion are transmitted along the surface of the Earth's crust.

The transit velocity of the vibrations of the first preliminary tremor, namely, V_1, is very great and no known rock has an elastic modulus sufficiently large to propagate with such a high velocity, whether the vibrations be longitudinal or transverse. Hence we must conclude that the waves of the first preliminary tremor are transmitted along some path within the Earth's crust. As, however, the duration of the first preliminary tremor at a given station is very nearly proportional to the arcual distance between the latter and the earthquake origin, it seems likely that the waves of the first preliminary tremor are transmitted parallel to the surface of the Earth and at a probably constant depth below it; the law of the first preliminary tremor, or generally the preliminary tremor, being explained on the supposition that the waves of the first and second preliminary tremors and of the principal portion are all generated simultaneously at the earthquake origin, but are gradually separated from one another as the disturbance spreads from the latter on account of the difference of the transit velocities. The layer, along which the high velocity (V_1) waves are propagated may probably mark the limit beyond which the seismic waves are, on account of certain physical properties of the underlying me-

*Not definitely known.

dium, unable to penetrate; or may be, as Professor NAGAOKA suggests, one of the maximum transit velocity. A very rough calculation, based on the relation of the duration of the first preliminary tremor and the epicentral distance, and on the value to the different velocities, gives 600^{km} or about 400 miles, as the probable depth of the layer along which the vibrations of the first preliminary tremor are propagated.

It is probable that the waves having velocities V_2 and V_3 are transmitted along layers at some smaller depths within the Earth's crust.

PROPAGATION OF THE SEISMIC MOTION COMPLETELY AROUND THE EARTH. Let T be the observing station and C the earthquake origin. Then there are three sets of motion, which can be distinguished and which we shall denote respectively W_1, W_2 and W_3 waves:

Firstly, the W_1 waves are those propagated from C to T along the shortest path, parallel to the surface, namely along the minor arc;

Secondly, the W_2 waves are those propagated from C in the opposite direction and arriving at T after passing through the antipode of C, namely, along the major arc; and

Thirdly, the W_3 waves are the W_1 waves which are propagated beyond T in the same direction, and again arriving at T, after making one complete circuit of the Earth.

The identification of the W_3 waves is possible only in a very small number of cases; that of the W_2 waves is, however, more definite, being usually characterized by the fact that their period is much slower than those of the preceding vibrations which form the end portion of the W_1 waves.

The average period of the W_2 waves is, with a few exceptions, very uniform and gives a mean value of 20.4 sec., which is identical with the predominating period in the third phase of the principal portion; the period of the W_3 waves is also probably nearly the same as that of the W_2 waves. These facts seem to indicate that the W_2 and W_3 waves are the same as those which constitute the third phase of the principal portion of the earthquake proper.

The time interval between the arrival of the W_1 and of the W_3 waves is 3h. 20m. 46s., this agrees with the time that would be taken by the vibrations in the third phase of the principal portion in making one complete circuit around the Earth, with the velocity of 3.3^{km} per second.

THE SAN FRANCISCO EARTHQUAKE OBSERVED IN TOKIO. As an example of a large distant earthquake observed in Tokio, I may mention the great shock of April 18, last. The time of commencement in Tokio of the earthquake

was 5h. 24m. 35s. a.m. (Pacific time;) the total duration of motion being 5 hours. The duration of the first preliminary tremor was 9m. 49s., from which the approximate arcual distance between the origin of the earthquake and the observing place was calculated to be about 5400 miles, and the time of the occurrence at the origin of the shock to be about 5h. 13 m. 5s., A. M. (P. S. T.)

The first displacement of the well-defined horizontal vibration at the commencement of the second preliminary tremor, was directed toward S 27° W.; the counter displacement being directed towards N.E. It will be observed that the directions of these movements were approximately equal to the direction of the great circle joining Tokio with the origin of disturbance, namely S.W. and N.E.

At about 7h. 31m. A. M., (P. S. T.) namely, 2h. 6m. 35s. after the commencement of the disturbance, there began vibrations which correspond to the same earthquake motion propagated along the major arc of the Earth, namely, which traveled from the center in a southeastern direction, through South America, the Atlantic and the Indian Oceans.

As other examples of large earthquakes which disturbed the west or Pacific Coast of the American continent, I may mention the following:

Alaska earthquake on September 3d and 10th, 1899, and on October 9th, 1900.

Central American earthquakes, on April 18th and September 22nd, 1902.

Panama, Colombia and Equador earthquake, on January 31st, 1906.

Now the whole Pacific Coast, which forms one of the most active seismic districts in the world, is frequently visited by earthquakes of different size and intensity. Large destructive earthquakes have, however, a tendency to happen in groups, namely, they occur at different parts of a given region or zone in the course of a few years. Thus, as mentioned above, there were, between September, 1899, and January, 1906, a series of six extensive disturbances which affected the whole west coast from Alaska down to South America, indicating that these earthquakes were of no local character, but that great stresses were going on along the Pacific border, such that the extension of the seismic disturbance to the coast of the United States would have been a most natural event to be expected. The great earthquake of April 18th last, may therefore be regarded as having completed the continuity of the manifestation of the seismic activity along this part of the world. Now an earthquake is caused by the existence of a weak

point underground, which, reaching the limit, finally gives rise to a sudden disturbance which forms the source of wave motion propagated through the rock and the soil. A very extensive earthquake, such as that of April 18th, may thus be regarded as having removed a considerable unstability existing in this part of the Earth's crust; those regions most violently shaken becoming seismically the safest place for a certain time interval to come. As a matter of fact, there has been no case in which great earthquakes have originated successively at one and the same center.

The small after shocks which will continue to shake the different portions of the western coast for a few years, are not of a dangerous nature. On the contrary, it is absolutely necessary that these small shocks should occur, as the disturbed Earth's crust settles, by means of these shocks, into the original condition of equilibrium; and even in the case of a future earthquake, after a number of years, the intensity of motion would not be so violent, and it will be an easy task to make architectural and engineering works perfectly earthquake proof.

San Francisco, June 9, 1906.

ECLIPSES OF THE SATELLITES OF SATURN, OCCURRING IN THE YEAR 1906.

By Hermann Struve.

The interesting observations of the eclipses of the satellites of *Saturn*, being of the greatest value for deriving the diameters of the planets, for correcting the elements of the orbits and for conclusions as to the dimensions of the satellites, and some physical questions, it is to be hoped, that the favorable opportunities for observing the eclipses during the present and next year will not be lost. The attention of astronomers, who are in possession of powerful instruments is particularly directed to these phenomena. But in the case of the brighter satellites, *Tethys*, *Dione*, *Rhea* and *Titan*, instruments of moderate size also could be employed with success.

In the present year the cycle of eclipses extends over all interior satellites from *Mimas* to *Rhea; Titan* and *Hyperion* will be eclipsed only during the next opposition. To facilitate these observations, I have calculated the approximate times and places of the eclipses for every day from June 1st to the

end of the year. These data might be useful, especially in the record of the reappearances. Before opposition only the disappearances, after the opposition, only the reappearances are visible from the Earth. The Greenwich mean times are given to a minute and cannot deviate much from the truth. The columns headed s and p, give the geocentric place of the satellite at the time of the eclipse, i.e., the distance of the satellite from the limb of the planet and the position angle, counted from the north point of the minor axis of the disc. As may be seen, the reappearances happen in the present year in general at greater distances from the limb, than the disappearances, and are therefore easier to observe. But it would be of special interest to have the observations distributed on both sides of the planet. The duration of the appearances may be in central eclipses in the case of *Rhea*, several minutes, in the case of *Tethys* and *Dione*, about one minute, in the case of *Mimas* and *Enceladus* only a few seconds. Of course the beginning and ending of the appearance, the seeing and other particulars must be noted by the observers.

At the end of the following tables are given the approximate Greenwich times, when the shadows of the satellites *Tethys, Dione, Rhea* cross the minor axis of the disc, and also their distance from the center of the disc at the time of conjunction. It seems to me doubtful, whether the shadows of *Saturn's* satellites, excepting the shadow of *Titan*, can be seen on the disc, my own search for them with the thirty-inch Pulwoka refractor in the years 1891-92, having been without success. By other observers the shadows were reported to be discernible and it would be of interest to decide the question at this time.

Similar tables were inserted by me in the *Monthly Notices*, Vol. LXIV, for the eclipses of the three innermost satellites in the two foregoing years. Only a few observations have come, hitherto, to my knowledge. But it is to be expected, that the more favorable conditions in the present year, and next year, will procure more numerous observations, and I beg the observers to send them to the Königliche Sternwarte, Berlin, where they will be duly collected and discussed, and will also serve in the preparation of the tables for next year.

Royal Observatory, Berlin, March, 1906.

ECLIPSES OF THE SATELLITES OF SATURN 1906.

DISAPPEARANCE BEFORE OPPOSITION.

s. p. denote the geocentric place of the satellite at the time of its disappearance, i. e., the distance from the limb of the planet and the position angle, counted from the north point of the minor axis to the West.

1906		Gr. M.T.	s. p. (West)
June 1	Mi	10h 42m	2.0″ 87°
	En	15 49	2.2 81
	Di	22 33	2.6 74
2	Mi	9 19	2.0 87
	Te	14 0	2.3 76
3	En	0 42	2.3 81
	Mi	7 56	2.0 87
4	Mi	6 33	2.0 87
	En	9 35	2.3 81
	Te	11 19	2.3 76
	Di	16 14	2.6 74
5	Mi	5 10	2.0 87
	En	18 28	2.3 81
6	Mi	3 47	2.0 87
	Te	8 37	2.4 76
7	Mi	2 24	2.0 87
	En	3 21	2.3 81
	Di	9 55	2.7 75
8	Mi	1 1	2.0 87
	Te	5 56	2.4 76
	En	12 14	2.3 81
	Mi	23 38	2.0 87
9	En	21 7	2.3 81
	Mi	22 15	2.0 87
10	Te	3 15	2.4 76
	Di	3 36	2.7 75
	Mi	20 52	2.0 87
11	En	6 0	2.3 81
	Mi	19 29	2.0 87
12	Te	0 33	2.4 76
	En	14 53	2.4 81
	Mi	18 6	2.0 87
	Di	21 18	2.8 75
13	Mi	16 44	2.0 87
	Te	21 52	2.5 76
	En	23 46	2.4 81
14	Mi	15 21	2.0 87
	Rh	16 11	0.3 62
15	En	8 39	2.4 81
	Mi	13 58	2.0 87
	Di	14 59	2.8 75
	Te	19 10	2.5 76
16	Mi	12 35	2.0 87
	En	17 32	2.4 81
17	Mi	11 12	2.0 87
	Te	16 28	2.5 76
18	En	2 25	2.4 81
	Di	8 40	2.9 75
	Mi	9 49	2.1 87
19	Rh	4 26	0.8 64
	Mi	8 26	2.1 87
	En	11 18	2.4 81
	Te	13 47	2.5 76
20	Mi	7 3	2.1 87
	En	20 12	2.4 81
21	Di	2 21	2.9 75
	Mi	5 41	2.1 87
	Te	11 5	2.5 76
22	Mi	4 17	2.1 87
	En	5 5	2.4 81
23	Mi	2 54	2.1 87
	Te	8 24	2.5 76
	En	13 58	2.4 81
	Rh	16 46	1.1 65
	Di	20 2	2.9 75
24	Mi	1 31	2.1 87
	En	22 51	2.4 81
June 25	Mi	0h 8m	2.1″ 87°
	Te	5 43	2.5 76
	Mi	22 45	2.1 87
26	En	7 44	2.4 81
	Di	13 44	2.9 75
	Mi	21 22	2.0 86
27	Te	3 1	2.4 76
	En	16 37	2.3 81
	Mi	19 59	2.0 86
28	Rh	5 8	1.3 65
	Mi	18 37	2.0 86
29	Te	0 19	2.4 76
	En	1 30	2.3 81
	Di	7 25	2.8 75
	Mi	17 14	2.0 86
30	En	10 24	2.3 81
	Mi	15 51	2.0 86
	Te	21 38	2.4 76
July 1	Mi	14 28	2.0 86
	En	19 17	2.3 81
2	Di	1 6	2.8 75
	Mi	13 5	1.9 86
	Rh	17 31	1.5 65
	Te	18 57	2.3 76
3	En	4 10	2.2 80
	Mi	11 42	1.9 86
4	Mi	10 19	1.9 86
	En	13 3	2.2 80
	Te	16 15	2.3 76
	Di	18 47	2.8 75
5	Mi	8 56	1.9 86
	En	21 57	2.2 80
6	Mi	7 34	1.9 86
	Te	13 34	2.2 75
7	Rh	5 54	1.6 65
	Mi	6 11	1.9 86
	En	6 51	2.2 80
	Di	12 28	2.7 74
8	Mi	4 48	1.8 86
	Te	10 52	2.2 75
	En	15 44	2.1 80
9	Mi	3 25	1.8 86
10	En	0 37	2.1 80
	Mi	2 2	1.8 85
	Di	6 9	2.7 74
	Te	8 11	2.2 75
11	Mi	0 39	1.8 85
	En	9 30	2.1 80
	Rh	18 17	1.6 64
	Mi	23 17	1.8 85
12	Te	5 30	2.1 75
	En	18 23	2.1 80
	Mi	21 54	1.8 85
	Di	23 51	2.6 74
13	Mi	20 32	1.8 85
14	Te	2 48	2.1 75
	En	3 16	2.0 80
	Mi	19 9	1.8 85
15	En	12 9	2.0 80
	Di	17 32	2.5 74
	Mi	17 46	1.8 85
16	Te	0 7	2.1 75
	Rh	6 41	1.6 64
	Mi	16 23	1.7 85
	En	21 2	2.0 80
17	Mi	15 0	1.7 85
	Te	21 25	2.1 74
July 18	En	5h 55m	1.9″ 80°
	Di	11 14	2.4 73
	Mi	13 37	1.7 85
19	Mi	12 14	1.7 85
	En	14 48	1.9 79
	Te	18 43	2.0 74
20	Mi	10 51	1.6 84
	Rh	19 5	1.5 63
	En	23 41	1.9 79
21	Di	4 55	2.3 73
	Mi	9 29	1.6 84
	Te	16 2	2.0 74
22	Mi	8 6	1.6 84
	En	8 34	1.9 79
23	Mi	6 43	1.6 84
	Te	13 20	1.9 73
	En	17 27	1.9 79
	Di	22 36	2.2 72
24	Mi	5 20	1.5 84
25	En	2 20	1.8 79
	Mi	3 57	1.5 84
	Rh	7 30	1.4 62
	Te	10 39	1.9 73
26	Mi	2 35	1.5 84
	En	11 13	1.8 78
	Di	16 17	2.1 72
27	Mi	1 12	1.4 83
	Te	7 58	1.8 73
	En	20 6	1.7 78
	Mi	23 49	1.4 83
28	Mi	22 27	1.4 83
29	En	5 0	1.7 78
	Te	5 17	1.8 73
	Di	9 59	2.0 71
	Rh	19 54	1.3 60
	Mi	21 4	1.4 83
30	En	13 53	1.6 78
	Mi	19 41	1.3 83
31	Te	2 35	1.7 72
	Mi	18 18	1.3 83
	En	22 46	1.6 78
Aug. 1	Di	3 40	1.9 71
	Mi	16 55	1.3 83
	Te	23 54	1.6 72
2	En	7 39	1.5 78
	Mi	15 32	1.3 83
3	Rh	8 18	1.2 58
	Mi	14 9	1.2 82
	En	16 32	1.5 78
	Te	21 12	1.5 71
	Di	21 22	1.8 70
4	Mi	12 46	1.2 82
5	En	1 26	1.4 77
	Mi	11 24	1.2 82
	Te	18 31	1.5 71
6	Mi	10 1	1.1 82
	En	10 20	1.4 77
	Di	15 3	1.7 69
7	Mi	8 39	1.1 82
	Te	15 49	1.4 70
	En	19 13	1.3 77
	Rh	20 43	1.1 56
8	Mi	7 16	1.1 81
9	En	4 6	1.3 77
	Mi	5 54	1.0 81
	Di	8 45	1.6 68
	Te	13 8	1.3 70

1906		Gr. M.T.	s. p. (West)	1906		Gr. M.T.	s. p. (West)	1906		Gr. M.T.	s. p. (West)
Aug. 10	Mi	4h 31m	1.0″ 81°	Aug 18	Te	23h 41m	1.0″ 68°	Aug. 28	En	8h 31m	0.5″ 73°
	En	13 0	1.2 76	19	Mi	14 43	0.7 79		Te	10 14	0.5 65
11	Mi	3 8	1.0 81	20	En	3 12	0.8 75		Di	12 36	0.6 60
	Te	10 26	1.2 70		Di	7 31	1.0 64	29	Mi	0 56	0.4 78
	En	21 53	1.2 76		Mi	13 21	0.7 79		En	17 24	0.4 73
12	Mi	1 45	1.0 81		Te	20 59	0.9 67		Mi	23 33	0.4 78
	Di	2 26	1.5 67	21	Rh	9 58	0.7 49	30	Te	7 32	0.4 64
	Rh	9 8	1.0 54		Mi	11 58	0.7 79		Rh	10 50	0.5 43
13	Mi	0 22	0.9 81		En	12 5	0.8 75		Mi	22 10	0.3 77
	En	6 46	1.1 76	22	Mi	10 35	0.6 79	31	En	2 17	0.3 72
	Te	7 45	1.1 69		Te	18 18	0.8 67		Di	6 18	0.5 59
	Mi	22 59	0.9 80		En	20 58	0.7 74		Mi	20 48	0.3 77
14	En	15 39	1.1 76	23	Di	1 13	0.9 63	Sept. 1	Te	4 51	0.3 63
	Di	20 7	1.3 66		Mi	9 12	0.6 79		En	11 10	0.2 72
	Mi	21 36	0.9 80	24	En	5 51	0.7 74		Mi	19 25	0.2 77
15	Te	5 3	1.1 69		Mi	7 50	0.6 78	2	Mi	18 2	0.2 77
	Mi	20 13	0.9 80		Te	15 36	0.7 66		En	20 3	0.2 72
16	En	0 32	1.0 76	25	Mi	6 27	0.5 78		Di	23 59	0.3 58
	Mi	18 50	0.8 80		En	14 44	0.6 73	3	Te	2 10	0.2 62
	Rh	21 33	0.8 52		Di	18 54	0.8 62		Mi	16 39	0.1 76
17	Te	2 22	1.0 68		Rh	22 24	0.6 46		Rh	23 17	0.3 40
	En	9 26	0.9 76	26	Mi	5 4	0.5 78	4	En	4 57	0.1 71
	Di	13 49	1.2 65		Te	12 55	0.6 66		Mi	15 17	0.1 76
	Mi	17 27	0.8 80		En	23 37	0.6 73		Te	23 29	0.1 61
18	Mi	16 5	0.8 80	27	Mi	3 41	0.5 78				
	En	18 19	0.9 75	28	Mi	2 19	0.4 78				

REAPPEARANCE AFTER OPPOSITION.

s. p. denote the geocentric place of the satellite at the time of its reappearance, i. e., the distance from the limb of the planet and the position angle, counted from the north point of the minor axis to the East.

1906		Gr. M.T.	s. p. (East)	1906		Gr. M.T.	s. p. (East)	1906		Gr. M.T.	s. p. (East)
Sept. 4	Rh	1h 37m	0.1″ 37°	Sept 18	En	0h 22m	0.9″ 71°	Oct. 2	Mi	1h 33m	1.3″ 71°
	En	7 28	0.0 71		Te	7 14	1.3 61	3	Mi	0 11	1.3 71
	Mi	17 31	0.0 72		Mi	20 50	0.6 71		En	2 11	1.8 71
5	Te	2 1	0.0 59	19	En	9 16	1.0 71		Di	5 31	3.1 61
	Mi	16 8	0.0 72		Di	12 57	1.8 59		Te	9 46	2.4 62
	En	16 21	0.1 71		Mi	19 28	0.7 71		Mi	22 48	1.3 71
	Di	20 27	0.1 57	20	Te	7 33	1.4 61	4	En	11 4	1.9 71
6	Mi	14 45	0.0 72		Mi	18 5	0.7 71		Mi	21 25	1.4 71
	Te	23 20	0.2 59		En	18 10	1.1 71	5	Te	7 6	2.5 62
7	En	1 15	0.2 71	21	Mi	16 42	0.7 71		Rh	17 2	4.4 50
	Mi	13 23	0.1 72	22	Te	1 52	1.6 61		En	19 57	1.9 71
8	En	10 8	0.2 71		En	3 3	1.1 71		Mi	20 3	1.4 71
	Mi	12 0	0.1 72		Rh	3 34	2.6 46		Di	23 14	3.3 62
	Di	14 5	0.5 57		Di	6 41	2.1 60	6	Mi	18 40	1.4 71
	Rh	14 6	0.7 40		Mi	15 20	0.8 71	7	Te	4 25	2.6 62
	Te	20 39	0.4 59	23	En	11 57	1.2 71		En	4 52	2.0 71
9	Mi	10 37	0.2 72		Mi	13 57	0.8 71		Mi	17 17	1.4 71
	En	19 2	0.3 71		Te	23 11	1.7 61	8	En	13 46	2.0 71
10	Mi	9 15	0.2 72	24	Mi	12 34	0.9 71		Mi	15 55	1.5 71
	Te	17 58	0.5 60		En	20 51	1.2 71		Di	16 56	3.5 62
11	En	3 55	0.4 71	25	Di	0 24	2.4 60	9	Te	1 44	2.7 62
	Di	7 48	0.8 58		Mi	11 12	0.9 71		Mi	14 32	1.5 71
	Mi	7 52	0.3 72		Te	20 30	1.9 61		En	22 39	2.1 71
12	Mi	6 29	0.3 72	26	En	5 44	1.3 71	10	Rh	5 32	4.9 51
	En	12 49	0.5 71		Mi	9 49	1.0 71		Mi	13 9	1.6 71
	Te	15 17	0.7 60		Rh	16 3	3.2 48		Te	23 3	2.9 62
13	Rh	2 35	1.3 42	27	Mi	8 26	1.0 71	11	En	7 33	2.2 71
	Mi	5 7	0.4 72		En	14 38	1.4 71		Di	10 39	3.7 62
	En	21 43	0.6 71		Te	17 49	2.0 61		Mi	11 46	1.6 71
14	Di	1 31	1.2 58		Di	18 6	2.6 61	12	Mi	10 24	1.6 71
	Mi	3 44	0.4 72	28	Mi	7 4	1.1 71		En	16 26	2.2 71
	Te	12 36	0.9 60	29	Mi	5 41	1.1 71		Te	20 22	3.0 62
15	Mi	2 21	0.4 72		Te	15 8	2.1 61	13	Mi	9 1	1.7 71
	En	6 36	0.7 71		En	23 31	1.5 71	14	En	1 19	2.3 71
16	Mi	0 59	0.5 72	30	Mi	4 18	1.2 71		Di	4 21	3.9 62
	Te	9 55	1.1 60		En	8 25	1.6 71		Mi	7 38	1.7 71
	En	15 29	0.8 71		Di	11 48	2.9 61		Te	17 41	3.1 62
	Di	19 14	1.5 59	Oct. 1	Mi	2 56	1.2 71		Rh	18 1	5.4 52
	Mi	23 36	0.5 72		Rh	4 32	3.8 49	15	Mi	6 16	1.7 71
17	Rh	15 4	2.0 44		Te	12 27	2.3 62		En	10 12	2.4 71
	Mi	22 13	0.6 71		En	17 18	1.7 71	16	Mi	4 53	1.8 71

1906		Gr. M.T.	s. p. (East)
Oct. 16	Te	15h 0m	3.2" 62°
	En	19 6	2.4 71
	Di	22 4	4.1 62
17	Mi	3 30	1.8 71
18	Mi	2 8	1.8 71
	En	3 59	2.5 71
	Te	12 19	3.3 62
19	Mi	0 45	1.9 71
	Rh	6 30	5.8 53
	En	12 52	2.6 71
	Di	15 46	4.2 62
	Mi	23 23	1.9 71
20	Te	9 38	3.4 63
	En	21 45	2.6 71
	Mi	22 0	1.9 71
21	Mi	20 37	1.9 71
22	En	6 39	2.7 71
	Te	6 58	3.5 63
	Di	9 28	4.4 63
	Mi	19 15	1.9 71
23	En	15 32	2.7 71
	Mi	17 52	2.0 71
	Rh	19 0	6.2 54
24	Te	4 17	3.6 63
	Mi	16 29	2.0 71
25	En	0 26	2.8 71
	Di	3 11	4.5 63
	Mi	15 7	2.0 71
26	Te	1 36	3.6 63
	En	9 19	2.8 71
	Mi	13 44	2.1 71
27	Mi	12 22	2.1 71
	En	18 13	2.8 71
	Di	20 53	4.7 63
	Te	22 55	3.7 63
28	Rh	7 29	6.6 55
	Mi	10 59	2.1 71
29	En	3 6	2.9 71
	Mi	9 36	2.2 71
	Te	20 14	3.8 63
30	Mi	8 13	2.2 71
	En	12 0	2.9 71
	Di	14 36	4.8 63
31	Mi	6 50	2.2 71
	Te	17 33	3.8 63
	En	20 53	2.9 71
Nov. 1	Mi	5 28	2.2 71
	Rh	19 58	6.9 55
2	Mi	4 5	2.2 71
	En	5 47	3.0 72
	Di	8 19	5.0 64
	Te	14 52	3.9 64
3	Mi	2 43	2.3 71
	En	14 41	3.0 72
4	Mi	1 20	2.3 71
	Te	12 12	3.9 64
	En	23 34	3.0 72
	Mi	23 57	2.3 71
5	Di	2 2	5.1 64
	Mi	22 35	2.3 72
6	En	8 27	3.0 72
	Rh	8 28	7.1 56
	Te	9 32	3.9 64
	Mi	21 12	2.3 72
7	En	17 21	3.0 72
	Di	19 45	5.2 64
	Mi	19 50	2.3 72
8	Te	6 51	4.0 64
	Mi	18 27	2.3 72
9	En	2 15	3.0 72
	Mi	17 4	2.4 72
10	Te	4 10	4.0 64
	En	11 8	3.1 72
	Di	13 28	5.3 64
	Mi	15 42	2.4 72
	Rh	20 57	7.3 56

1906		Gr. M.T.	s. p. (East)
Nov. 11	Mi	14h 19m	2.4" 72°
	En	20 1	3.1 72
12	Te	1 29	4.0 64
	Mi	12 56	2.4 72
13	En	4 55	3.1 72
	Di	7 10	5.4 64
	Mi	11 34	2.4 72
	Te	22 48	4.1 64
14	Mi	10 11	2.4 72
	En	13 49	3.1 72
15	Mi	8 48	2.4 72
	Rh	9 26	7.5 57
	Te	20 7	4.1 64
	En	22 42	3.1 72
16	Di	0 53	5.4 64
	Mi	7 26	2.5 72
17	Mi	6 3	2.5 72
	En	7 36	3.1 72
	Te	17 26	4.1 64
18	Mi	4 41	2.5 72
	En	16 30	3.2 72
	Di	18 35	5.5 64
19	Mi	3 18	2.5 72
	Te	14 45	4.1 64
	Rh	21 56	7.6 57
20	En	1 23	3.2 72
	Mi	1 55	2.5 72
21	Mi	0 33	2.5 72
	En	10 17	3.2 72
	Te	12 5	4.2 64
	Di	12 18	5.4 65
	Mi	23 10	2.5 72
22	En	19 11	3.2 72
	Mi	21 47	2.5 72
23	Te	9 25	4.2 65
	Mi	20 25	2.5 72
24	En	4 4	3.2 72
	Di	6 0	5.4 65
	Rh	10 25	7.6 58
	Mi	19 2	2.5 72
25	Te	6 44	4.2 65
	En	12 57	3.2 72
	Mi	17 39	2.5 72
26	Mi	16 17	2.5 72
	En	21 51	3.2 72
	Di	23 43	5.4 65
27	Te	4 3	4.2 65
	Mi	14 54	2.5 72
28	En	6 44	3.2 73
	Mi	13 31	2.5 72
	Rh	22 54	7.6 58
29	Te	1 23	4.2 65
	Mi	12 9	2.5 73
	En	15 38	3.2 73
	Di	17 26	5.4 65
30	Mi	10 46	2.5 73
	Te	22 42	4.1 65
Dec. 1	En	0 32	3.2 73
	Mi	9 23	2.5 73
2	Mi	8 0	2.5 73
	En	9 25	3.2 73
	Di	11 9	5.4 65
	Te	20 1	4.1 65
3	Mi	6 38	2.5 73
	Rh	11 23	7.5 59
	En	18 19	3.2 73
4	Mi	5 15	2.5 73
	Te	17 20	4.1 65
5	En	3 13	3.2 73
	Mi	3 52	2.5 73
	Di	4 51	5.3 66
6	Mi	2 30	2.5 73
	En	12 6	3.2 73
	Te	14 39	4.1 66
7	Mi	1 7	2.4 73
	En	21 0	3.2 73

1906		Gr. M.T.	s. p. (East
Dec. 7	Di	22h 34m	5.3" 66°
	Mi	23 44	2.4 73
	Rh	23 52	7.4 59
8	Te	11 58	4.1 66
	Mi	22 22	2.4 73
9	En	5 54	3.2 73
	Mi	20 59	2.4 73
10	Te	9 18	4.0 66
	En	14 47	3.2 73
	Di	16 17	5.3 66
	Mi	19 37	2.4 73
11	Mi	18 14	2.4 74
	En	23 41	3.2 74
12	Te	6 37	4.0 66
	Rh	12 21	7.3 60
	Mi	16 51	2.4 74
13	En	8 34	3.2 74
	Di	9 59	5.2 66
	Mi	15 29	2.4 74
14	Te	3 56	3.9 66
	Mi	14 6	2.4 74
	En	17 28	3.1 74
15	Mi	12 43	2.3 74
16	Te	1 16	3.9 66
	En	2 22	3.1 74
	Di	3 42	5.1 66
	Mi	11 21	2.3 74
17	Rh	0 50	7.2 60
	Mi	9 58	2.3 74
	En	11 15	3.1 74
	Te	22 35	3.8 66
18	Mi	8 36	2.3 74
	En	20 9	3.0 74
	Di	21 25	5.0 67
19	Mi	7 13	2.3 74
	Te	19 54	3.8 66
20	En	5 2	3.0 74
	Mi	5 50	2.3 74
21	Mi	4 28	2.3 74
	Rh	13 19	7.0 61
	En	13 56	3.0 74
	Di	15 8	4.9 67
	Te	17 13	3.7 67
22	Mi	3 5	2.3 74
	En	22 49	2.9 74
23	Mi	1 43	2.2 75
	Te	14 32	3.7 67
24	Mi	0 20	2.2 75
	En	7 43	2.9 74
	Di	8 50	4.8 67
	Mi	22 57	2.2 75
25	Te	11 52	3.6 67
	En	16 37	2.8 74
	Mi	21 35	2.2 75
26	Rh	1 48	6.8 62
	Mi	20 12	2.1 75
27	En	1 30	2.8 74
	Di	2 33	4.7 67
	Te	9 11	3.6 67
	Mi	18 49	2.1 75
28	En	10 24	2.7 75
	Mi	17 27	2.1 75
29	Te	6 30	3.5 67
	Mi	16 4	2.0 76
	En	19 18	2.7 75
	Di	20 16	4.6 68
30	Rh	14 18	6.6 63
	Mi	14 42	2.0 76
31	Te	3 50	3.4 68
	En	4 11	2.6 75
1907	Mi	13 19	2.0 76
Jan. 1	En	13 5	2.6 75
	Di	13 58	4.5 68
2	Te	1 9	3.3 68
4	Rh	2 46	6.3 64

SHADOWS OF THE SATELLITES *TETHYS, DIONE, RHEA.*

Crossing the minor axis of the disc at the distance y from the center.

1906		Gr. M.T.	y (South)
June 25	Di	6.2h	5.3"
	Rh	23.5	7.7
26	Te	5.7	4.6
27	Di	23.9	5.3
28	Te	3.0	4.6
30	Te	0.3	4.6
	Rh	11.9	7.7
	Di	17.6	5.3
July 1	Te	21.6	4.6
3	Di	11.3	5.3
	Te	18.9	4.6
5	Rh	0.4	7.7
	Te	16.2	4.6
6	Di	5.0	5.3
7	Te	13.5	4.6
8	Di	22.7	5.3
9	Te	10.8	4.6
	Rh	12.8	7.6
11	Te	8.1	4.6
	Di	16.4	5.3
13	Te	5.5	4.6
14	Rh	1.2	7.6
	Di	10.1	5.3
15	Te	2.8	4.6
17	Te	0.1	4.6
	Di	3.8	5.3
18	Rh	13.7	7.6
	Te	21.4	4.7
19	Di	21.5	5.3
20	Te	18.7	4.7
22	Di	15.2	5.3
	Te	16.0	4.7
23	Rh	2.1	7.5
24	Te	13.3	4.7
25	Di	8.9	5.3
26	Te	10.6	4.7
27	Rh	14.6	7.5
28	Di	2.6	5.3
	Te	7.9	4.7
30	Te	5.3	4.7
	Di	20.2	5.3
Aug. 1	Te	2.5	4.7
	Rh	3.1	7.4
2	Di	13.9	5.2
	Te	23.9	4.7
4	Te	21.2	4.7
5	Di	7.6	5.2
	Rh	15.5	7.4
6	Te	18.5	4.7
8	Di	1.3	5.2
	Te	15.8	4.7
10	Rh	3.9	7.3
	Te	13.1	4.7
	Di	19.0	5.2
12	Te	10.4	4.7
13	Di	12.7	5.2
14	Te	7.7	4.7
	Rh	16.4	7.2
16	Te	5.0	4.7
	Di	6.4	5.2
18	Te	2.3	4.7
19	Di	0.0	5.1
	Rh	4.8	7.2
	Te	23.6	4.7
21	Di	17.8	5.1
	Te	20.9	4.7
23	Rh	17.3	7.1
	Te	18.2	4.7
24	Di	11.4	5.1
25	Te	15.5	4.7
27	Di	5.1	5.1

1906		Gr. M.T.	y (South)
Aug. 27	Te	12.9h	4.7"
28	Rh	5.7	7.1
29	Te	10.2	4.7
	Di	22.8	5.1
31	Te	7.5	4.7
Sept. 1	Di	16.5	5.0
	Rh	18.2	7.0
2	Te	4.8	4.6
4	Te	2.1	4.6
	Di	10.2	5.0
5	Te	23.4	4.6
6	Rh	6.6	7.0
7	Di	3.9	5.0
	Te	20.7	4.6
9	Te	18.0	4.6
	Di	21.6	5.0
10	Rh	19.1	6.8
11	Te	15.4	4.6
12	Di	15.3	4.9
13	Te	12.7	4.6
15	Rh	7.6	6.7
	Di	9.0	4.9
	Te	10.0	4.6
17	Te	7.3	4.6
18	Di	2.7	4.9
19	Te	4.6	4.6
	Rh	20.0	6.7
20	Di	20.4	4.8
21	Te	1.9	4.5
22	Te	23.2	4.5
23	Di	14.1	4.8
24	Rh	8.5	6.6
	Te	20.5	4.5
26	Di	7.8	4.8
	Te	17.8	4.5
28	Te	15.1	4.5
	Rh	20.9	6.5
29	Di	1.5	4.8
30	Te	12.5	4.5
Oct. 1	Di	19.1	4.7
2	Te	9.8	4.5
3	Rh	9.4	6.4
4	Te	7.1	4.4
	Di	12.9	4.7
6	Te	4.4	4.4
7	Di	6.5	4.6
	Rh	21.8	6.3
8	Te	1.7	4.4
9	Te	23.0	4.4
10	Di	0.1	4.6
11	Te	20.3	4.4
12	Rh	10.3	6.2
	Di	17.9	4.6
13	Te	17.7	4.4
15	Di	11.6	4.5
	Te	15.0	4.3
16	Rh	22.7	6.1
17	Te	12.3	4.3
18	Di	5.4	4.5
19	Te	9.6	4.3
20	Di	23.1	4.5
21	Te	6.9	4.3
	Rh	11.2	6.0
23	Te	4.2	4.3
	Di	16.8	4.4
25	Te	1.5	4.2
	Rh	23.6	5.9
26	Di	10.5	4.4
	Te	22.9	4.2
28	Te	20.2	4.2
29	Di	4.2	4.3

1906		Gr. M.T.	y (South)
Oct. 30	Rh	12.1h	5.8"
	Te	17.5	4.2
31	Di	21.9	4.3
Nov. 1	Te	14.8	4.1
3	Te	12.1	4.1
	Di	15.6	4.2
4	Rh	0.6	5.7
5	Te	9.5	4.1
6	Di	9.3	4.2
7	Te	6.8	4.1
8	Rh	13.0	5.6
9	Di	3.0	4.1
	Te	4.1	4.0
11	Te	1.4	4.0
	Di	20.7	4.1
12	Te	22.7	4.0
13	Rh	1.5	5.5
14	Di	14.4	3.9
	Te	20.0	4.0
16	Te	17.3	3.9
17	Di	8.1	3.9
	Rh	14.0	5.4
18	Te	14.7	3.9
20	Di	1.8	3.8
	Te	12.0	3.9
22	Rh	2.4	5.2
	Te	9.3	3.9
	Di	19.5	3.8
24	Te	6.6	3.8
25	Di	13.2	3.7
26	Te	3.9	3.8
	Rh	14.9	5.1
28	Te	1.3	3.8
	Di	6.9	3.7
29	Te	22.6	3.7
Dec. 1	Di	0.6	3.6
	Rh	3.4	5.0
	Te	19.9	3.7
3	Te	17.2	3.6
	Di	18.3	3.6
5	Te	14.5	3.6
	Rh	15.8	4.8
6	Di	12.0	3.5
7	Te	11.8	3.6
9	Di	5.7	3.5
	Te	9.2	3.5
10	Rh	4.3	4.7
11	Te	6.5	3.5
	Di	23.4	3.4
13	Te	3.8	3.5
14	Rh	16.8	4.6
	Di	17.2	3.4
15	Te	1.1	3.5
16	Te	22.5	3.4
17	Di	10.8	3.3
18	Te	19.8	3.4
19	Rh	5.3	4.5
20	Di	4.5	3.3
	Te	17.1	3.4
22	Te	14.4	3.3
	Di	22.3	3.2
23	Rh	17.7	4.4
24	Te	11.7	3.3
25	Di	16.0	3.2
26	Te	9.0	3.3
28	Rh	6.2	4.3
	Te	6.3	3.2
	Di	9.7	3.1
30	Te	3.7	3.2
31	Di	3.4	3.1

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1906.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon.	July 5, 8h 27m, p. m.	Full Moon.....	August 4 5h 00m a. m.
Last Quarter.	July 14, 2h 13m, a. m.	Last Quarter...	August 11, 6h 47m, p. m.
New Moon	July 21, 4h 59m, a. m.	New Moon	August 19, 5h 27m, p. m.
First Quarter	July 28, 11h 56m, a. m.	First Quarter...	August 26, 4h 42m, p. m.

The Earth passes the aphelion point and reaches its farthest distance from the Sun on the night of July 23rd, about midnight, Pacific time.

There will be three eclipses during July and August. As is always the case when three eclipses occur in so brief a time, the first and third will be eclipses of the Sun, and the second an eclipse of the Moon.

The first, a partial eclipse of the Sun, will occur in the early morning of July 21st, Pacific time, and will be visible in far southern latitudes only.

The second is a total eclipse of the Moon, on August 4th, The beginning will be visible in the central and western portions of North America, and the eastern portions of Asia, and Australia, and the ending will be visible in Alaska and through Asia and Australia. The middle of totality will come at 5h. 1m. a.m. Pacific time, and the beginning and end of totality not quite an hour before and after that time. For the western part of the United States the Moon will set and the Sun will rise during totality.

The third is a partial eclipse of the Sun, on the afternoon of August 19, Pacific time. The eclipse will be visible mainly in the north polar regions, but it may be seen as a very small partial eclipse late in the afternoon in that part of the United States west of the Missouri and north of 40° latitude. The maximum obscuration is about one-third of the Sun's diameter and in regions far north of the United States. As seen from any part of the United States, the maximum obscuration will be much less.

At the beginning of July, *Mercury* is an evening star, setting an hour and one-half after sunset, and the interval is more than an hour until well after the middle of the month. So the first half of July affords the best opportunity of the year for seeing the planet as an evening star. The greatest east elongation, 26° 39′ is reached on July 15th, and is much above the average as the planet reaches its aphelion only a

few days later. The southerly motion of the planet after greatest elongation and the fact that it is in the portion of the orbit south of the ecliptic cause a rapid diminution of the interval between the setting of the Sun and of the planet, and it can be seen only a few days after the middle of July. It passes inferior conjunction with the Sun and becomes a morning star on August 12th. It then moves rapidly toward greatest west elongation (18° 12') and reaches this point on August 29th. It then rises an hour and one-half before sunrise, and it will be an easy object to see in the morning twilight for a week or so before and after the end of August.

Venus is an evening star setting a little more than two hours after sunset on July 1st, and less than an hour and three-fourths after on August 31st. It is still increasing in apparent distance from the Sun and will continue to do so until September 20th, but its motion among the stars is along a line farther and farther to the south of the Sun's position and this causes a hastening of the time of setting, which more than counterbalances the retardation due to increase of apparent distance from the Sun.

Mars is still an evening star on July 1st, but is too near the Sun to be seen. It passes conjunction with the Sun and becomes a morning star on July 15th, but does not move far enough away to be seen in the morning sky until nearly the end of August. It does not reach its maximum distance from the Earth until a fortnight after conjunction, since it is still receding from the Sun and will not reach its aphelion until the middle of October.

Jupiter is a morning star rising about an hour before sunrise on July 1st, and shortly after midnight on August 31st. It moves about 13° eastward among the stars from the eastern part of *Taurus* into *Gemini*, and at the end of August is south and west of *Castor* and *Pollux*, the brightest stars of the latter constellation.

Saturn is getting around into fair position for evening observation. It rises at about 11 P.M. on July 1st, and shortly before 7 P.M. on August 31st. It will reach opposition early in September. Its motion during the two months' period is westward and southward about 3° nearer the boundary line between *Aquarius* and *Pisces*. There are no bright stars near it.

Uranus rises shortly after 7 P.M. on July 1st, having passed opposition with the Sun on June 28th. By the end of August it rises about three P.M. It is therefore well up in the southeastern sky by the time twilight has disappeared. It

is in the constellation *Sagittarius* and moves about 2° westward during the period. During August it is about 2° north of *Lambda Sagittarii*, the third magnitude star in the handle of the milk dipper. It is just within the limit of naked eye visibility for ordinary eyes on clear moonless night.

Neptune passes conjunction with the Sun on July 2d, and becomes a morning star. It is in the western part of *Gemini*.

NOTES FROM PACIFIC COAST OBSERVATORIES.

LICK OBSERVATORY SEISMOGRAPH RECORD OF APRIL 18, 1906.

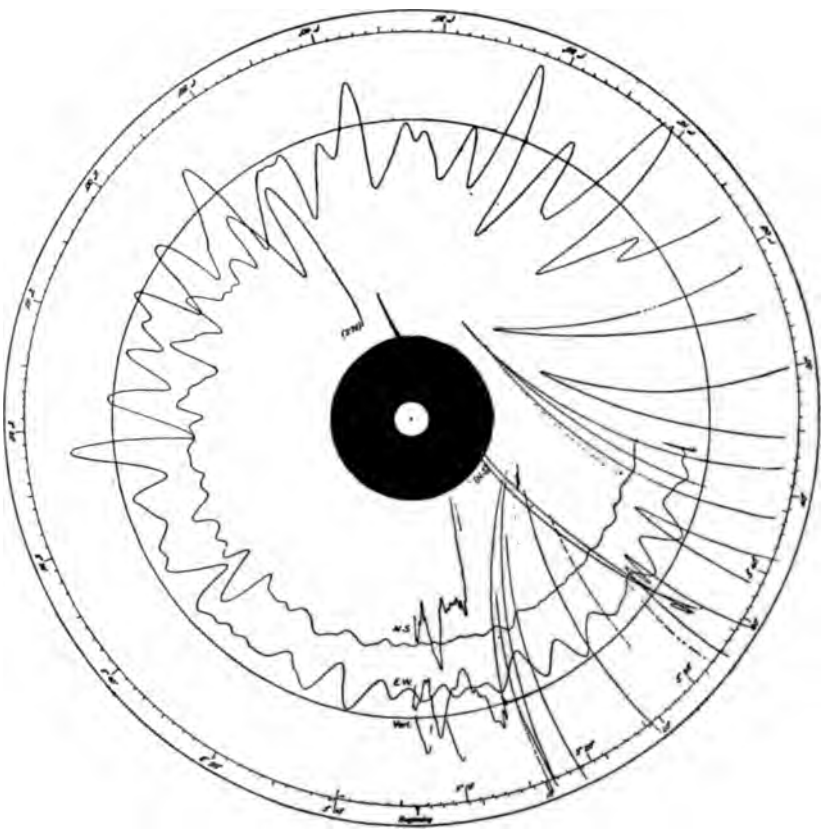
The intensity of the earthquake shock of April 18th at Mount Hamilton was less than the average intensity in the surrounding territory: on the unmodified* Rossi-Forel scale, it should be rated as about VII. In destructive violence the shock was not as severe as the local one of August 2nd, 1903, which received only passing notice outside Santa Clara County. The difference lay in the relation of displacement to time of displacement. The amplitude was several times as great in the recent earthquake, but the oscillation was much slower. Smooth vibrations with double amplitude of one or two centimeters (one-half or three-quarters of an inch,) pass unnoticed by the keenest observer, if their period be five seconds or more. Rapid or abrupt motions of one-tenth this amplitude are felt as sharp shocks.

The Ewing three-component† seismograph of the Lick Observatory gave a very satisfactory record, though the instrument was not designed for so great displacement and did not register all the motion. Professor OMORI has pronounced the record as of great value.

The north-south record is broken in two places; its three parts are marked N.S. or (N.S.) on the the accompanying reproduced tracing. The most remarkable north-south features are the long swings past the center of the plate and the indications of a wrench which seems to have jarred the pendulum from its bearings for a time. The vertical record leaves much to be desired. About ten seconds after the beginning, the pendulum was thrown from its bearings by the horizontal force of the heavy shock that also interrupted the north-south record, and was lodged against the standard. First, however, it registered a drop of nearly four centimeters, (one and one-half inches.) The east-west record is nearest complete, though the pen frequently passed beyond the cir-

*Nature, 42, 349, 1890; Publ. A. S. P., 7, 123, 1895.

†See illustrated description of early forms of this instrument in Encycl. Brit., article Seismometer.



Ewing Seismograph Record of the Lick Observatory, 1906.
April 18, 5:12:12 A. M., P. S. T.

To exhibit these components as simultaneous, each record has been rotated so as to bring its beginning opposite the origin of time

cumference of the revolving plate. At the end of three minutes and forty-nine seconds, when the plate stopped, the east-west pen continued to register slow vibrations of over half a centimeter, (one-quarter of an inch) double amplitude.

The record is complicated by the natural swing of the pendulums, and friction. To interpret the curves correctly, these must be taken into account. The horizontal pendulums swing with a free period of about seven seconds and come to rest from a maximum swing in a little over one complete vibration, if undisturbed. The vertical pendulum has a period of about four seconds, and will make about four complete swings. Small vibrations of the "earth particle," synchronous with the natural period of a pendulum, if continued, will soon set it swinging with large amplitude. In a less degree, oscillations of a different period will excite forced vibrations, with the resultant sort of compounding well illustrated by the last minute of the east-west record.

North, west and upward displacements are indicated by inward motion of the respective pens. To determine the real displacement in either component, the displacement shown in the cut, measured in the direction of a radius of the plate, after eliminating the instrumental effect, must be multiplied by the proper factor, following: N.S. 1.32, E.W. 1.44, Vert. 3.04. The actual direction and magnitude of the displacement at any moment, is obtained from the reduced component displacements, by simple compounding by parallelogram constructions.

JAMES D. MADDRILL.

ON THE EARTHQUAKE OF APRIL 18, 1906.

It is not necessary to say that the earthquake of April 18th was very severe on Mount Hamilton, but it is a matter for congratulation that the observatory suffered no serious injury. Director CAMPBELL was in Washington, D. C., at the time, and Astronomer TUCKER was in charge. It was found that the telephone connection with San José was destroyed, and, as fires were observed to break out at once in San Jose and San Francisco, the seriousness of the situation was soon realized. Professor TUCKER dispatched a bicycle messenger to San Jose, bearing the message that "The buildings and instruments of the Lick Observatory were not injured by the earthquake." All was confusion in San José and there was no telegraph or telephone communication with the outside world. The messenger therefore rode on to Berkeley, 75 miles

from Mount Hamilton, and delivered a copy of the message to President WHEELER of the University, late in the afternoon of the 18th. As it was not possible to send private dispatches, the message was delivered to the Associated Press, with the request that it be sent over the wires as soon as possible. This was done on the 19th, and the message was correctly published in many eastern papers of the 20th. A Chicago paper containing it overtook me in Iowa on the forenoon of the 20th, as I was speeding westward, and the relief afforded will not soon be forgotten. It was hoped that this information would reach all inquiring friends of the observatory, both in this country and abroad, but there soon appeared to be considerable doubt of this. On this account the message was at our request repeated a week later by the Associated Press.

The details of the earthquake are given for Mount Hamilton in Mr. MADDRILL'S note. The maximum double amplitudes of the motion here could scarcely be less than, and perhaps exceeded three inches. Fortunately, the period of vibration was long, and the buildings and instruments apparently had time to follow the earth motions. The tops of three large and one small brick chimneys were cracked, but not broken off. A great many old cracks in plastering were reopened, and many new cracks were formed. These apparently comprise the damage on the mountain. The brick and cement reservoirs and the water systems were not affected. Professor TUCKER'S observations with the meridian circle established that the instrument's position had not shafted appreciably. At my request, Dr. AITKEN and Dr. MOORE determined the position of the polar axis of the 36-inch refractor. They found no significant change.

This immunity, so to speak, is somewhat surprising, in view of the fact that the damage in San Jose, only thirteen miles directly west of us, was severe, and that in regions thirty to fifty miles east of us a large proportion of chimney tops were thrown down. Altitude alone can scarcely be a protective factor. The breaks in the rock strata between this observatory and the origin of disturbance—there are two narrow valleys between us and San Jose—are probably potent factors in reducing intensities. It is a familiar fact that earth waves of great destructiveness on one side of a mountain range often reappear destructively on the other side, as in the present case, with only minor destruction in the mountains themselves; but the explanation of these phenomena is usually not apparent. There can be no doubt,

however, that the rigid rock foundations of our buildings and instruments were exceedingly important elements in their stability, under the severe strains suddenly thrown upon them.

The indirect effects of the catastrophe upon the finances of the Lick Observatory and other State institutions cannot now be determined. Even though a way be found to maintain present incomes, there can be no doubt that further development, from State funds, will be seriously limited for many years to come. This is in no sense a statement of discouragement, as it is hoped that, as in the past, other sources of income may present themselves as needs arise.

The earthquake was destructive on a narrow belt extending along the coast from near Eureka in the north to Salinas in the south, a distance of about 300 miles. More than half the people of the State, and more than half the property are located in the affected district. The direct earthquake destruction was a minor matter, perhaps not exceeding $35,000,000, but the fire in San Francisco destroyed property valued at between $500,000,000 and $800,000,000, or roughly, one-fourth or one-fifth the assessable property of the State. One-third to one-fourth of this loss will probably be borne by insurance companies in other states and countries. Those State institutions which depend upon pro rata taxation for their support have lost a corresponding proportion of their income. The University of California loses $50,000 or $60,000 in this manner. It lost, besides, uninsured business property in San Francisco, whose annual rental was $60,000. The State of California will, no doubt, repair these losses, as far as it is financially able; and there are no people in the world more ready to support higher education in all its forms and phases, to the extent of their ability, than are the people who compose the commonwealth of California. They are both unusually practical and unusually interested in the ideal.

Four-fifths of the normal income of the Lick Observatory consist of State funds, assigned to it by the Regents of the University. These financial statements are made in deference to many inquiries from distant friends.

On the day following the earthquake, His Excellency, Governor GEO. C. PARDEE, appointed a State Commission to investigate the scientific aspects of the phenomenon. The Commission consists of Professor A. C. LAWSON, University of California, chairman; Professor J. C. BRANNER, Stanford University; Professor GEORGE DAVIDSON, University of Cal-

ifornia; Professor HARRY FIELDING REID, Johns Hopkins University; Dr. C. K. GILBERT, U. S. Geological Survey, Washington; Professor A. O. LEUSCHNER, University of California, Secretary; and Director W. W. CAMPBELL, Lick Observatory, University of California.

The Carnegie Institution of Washington has generously undertaken to defray the expenses of the investigation.

The work of the Commission is well organized and many facts of extreme interest have been established. The principal fact is that the earthquake was due to very extensive motion of the strata along a well-known geological fault that runs near the coast line. The motion was principally of the horizontal-shearing type, with few apparent evidences of any vertical component. The geological members of the commission have traced the *surface fissure* along the fault line practically continuously from the mouth of Alder Creek, just north of Point Arena, south to Fort Ross, where the fissure enters the ocean; thence from its reappearance in Tomales Bay, south to Bolinas Bay, where it again enters the ocean. It undoubtedly passes under the ocean about two miles out from the Golden Gate, as it re-enters the land some six or eight miles south of the Golden Gate and follows the old fault line continuously south-south-east to a point a short distance southeast of Salinas. On the east side of the fissure the strata have moved south, and on the west side they have moved north, relatively. The relative motion appears to be a maximum in the Tomales-Bolinas region, about 20-25 miles northwest of San Francisco. A public road crossing the fault line at right angles has now an offset of seventeen feet at the fault line. A large tree standing exactly on the east edge of the fissure is now twenty-four feet south from the small roots which it left in the west bank of the fissure. A path crossing the fissure is offset eighteen feet; three trees formerly stood in a row about seven feet east of a small house. The fissure passes between them and the house and they are now eighteen feet southerly from the house. A barn is situated exactly over the fissure, some four-fifths of it being on the west side. Although badly wrecked, the superstructure remains with its foundation west of the fissure, but that part of the foundation lying east of the fissure has moved southward under the barn, through eighteen feet. A fence crossing the fault line is offset eighteen feet at the fissure. About twenty miles westward from Mount Hamilton, on the fault line, the offsets are about eight and one-half feet, as a maximum. All the offsets referred to are in the thick loamy

soil, and it is possible that, on account of lag in the soft soil, the shear in the underlying rock stratum is larger.

Many interesting questions are raised as to disturbances in boundary lines between farms, in latitudes, azimuths, etc.

The same geological fault extends southeasterly throughout the State to the vicinity of the Colorado River, and perhaps further.

W. W. CAMPBELL.

THE CALIFORNIA EARTHQUAKE AT UKIAH.

The great earthquake of April 18th was very severe at Ukiah, 160 kilometers (96 miles) northwest of San Francisco. Many chimneys were thrown down and three brick buildings were partially wrecked. There were a series of shocks and reliable estimates of their duration vary from twenty seconds to one minute. The general direction of the waves seemed to be from the south to the north, although on the eastern side of the valley the damage to the buildings of the State Insane Asylum seemed to be almost entirely from the east and west movement.

At the Latitude Station no damage whatever, was done. The observatory clock, which faces south, was not stopped, but it lost six seconds during the disturbance, which is equivalent to being stopped for that length of time and then set to going again. The pier upon which the zenith telescope rests, is apparently not damaged, but the telescope was thrown considerably out of adjustment. It was out about fifteen seconds of arc in azimuth and the vertical axis was out in both directions, but not much more than sometimes results from extreme changes in temperature.

The first series of shocks was followed by three lighter ones, and the observed data for each are as follows:

Pacific Standard Time of Beginning	Duration	Direction	Intensity Rossi-Forel Scale
1906, April, 18d 5h 12m 17s a. m.	About 40s.	S. W. to N. E.	VIII. to IX.
18d 10h 4m 39s a. m.	About 10s.	S. W. to N. E.	IV.
18d 11h 39m 00s a. m.	About 30s.	S. W. to N. E.	III.
20d 12h 30m 53s a. m.			I.

The first time given is uncertain to the extent of five seconds, possibly more, either way. The other times are correct within two, or at the most, three seconds.

I was in the observatory at the time of the second series of shocks, at 10h 4m, and perceived the effect of the movement in the striding level, (east and west) of the zenith telescope. The bubble oscillated over about two divisions of the

level. The value of one division is 2.2″ and as the distance between the east and west leveling screws of the instrument is about 42 centimeters, the disturbance observed in the bubble was equivalent to the effect of raising and lowering one of the leveling screws, by 0.0005 centimeter. This shock was felt very distinctly and it is probable that the north and south component of the motion was much greater than the east and west one.

The fourth shock was not felt at all. It was detected during the progress of latitude observations by a movement of the bubbles of the latitude levels. The oscillation (north and south) was about one-half of one division, and the value of one division is 1.0″.

SIDNEY D. TOWNLEY.

International Latitude Observatory, Ukiah, California.

SEISMOLOGICAL STATIONS IN CALIFORNIA.

The need of several well equipped seismological stations in California has long been felt and has become more pressing through the recent earthquake and the desirability of accurate observations of the after-shocks. Several Duplex seismographs for recording the horizontal motion of the Earth's crust have been in operation in various parts of California for a number of years. But the only instruments available for recording the time element and the vertical component are two Ewing seismographs of which one is installed at the Lick Observatory and the other at the Students' Observatory. The chief disadvantages of these instruments are that they do not magnify the motion sufficiently, that they are not sufficiently sensitive and that the records are not continuous, the clock and disc being started by the shock. The Students' Observatory also has an old style seismograph of the Gray-Milne pattern, which originally gave a continuous record. But owing to the lack of an assistant to give it the constant care it requires, the instrument was altered some years ago so as to start with a shock, and later it was entirely abandoned. Since the earthquake of April 18th, it has been overhauled for want of a better instrument, and is now in operation. With the meager apparatus at their disposal, the Lick and the Students' Observatories, are, however, constantly securing such records as may be obtained. It might be mentioned here that aside from systematically observing earthquakes, these two observatories also keep a

complete meterological record in accordance with the instructions laid down by the U. S. Weather Bureau, for voluntary observers.

There is immediate prospect for an improved outfit in seismographs at at least three stations in California. The Carnegie Institution is installing seismographs at its Solar Observatory on Mount Wilson, the U. S. Weather Bureau on Mount Tamalpais, and Professor OMORI has brought one of his instruments, magnifying about 100 times, from Japan, and is setting it up at the Students' Observatory. The United States government ought to create a seismological commission with powers and functions similar to those under which the Japanese Imperial Commission is acting. The organization of seismological societies in various States, cooperating with the International Seismological Association, would also add much to the promotion of seismological research.

A. O. LEUSCHNER.

Berkeley, Cal., June 9th.

Members of the society who are located in California will render material aid in the investigation of earthquake phenomena in this State, if they will carefully record future shocks in accordance with the scheme outlined below. All communications should be addressed to the State Earthquake Commission, University of California, Berkeley, California.

Give information on the following:

1.—Postoffice address; town, county, and State.

2.—Place and date of observation.

3.—Name and address of the observer, if other than the writer.

4.—Give estimate of the intensity of the earthquake on the Rossi-Forel Scale. The Rossi-Forel Scale as amended by the commission is as follows:

I. *Perceptible,* only by delicate instruments.

II. *Very slight,* shocks noticed by few persons at rest.

III. *Slight shock,* of which duration and direction was noted by a number of persons.

IV. *Moderate shock,* reported by persons in motion; shaking of movable objects; cracking of ceilings.

V. *Smart shock,* generally felt; furniture shaken; some clocks stopped; some sleepers awakened.

VI. *Severe shock,* general awakening of sleepers; stopping of clocks; some window glass broken.

VII. *Violent shock,* overturning of loose objects; falling of plaster; striking of church bells; some chimneys fall.

VIII. Fall of chimneys; cracks in the walls of buildings.

IX. Partial or total destruction of some buildings.

X. Great disasters; overturning of rocks; fissures in the surface of the earth; mountain slides.

5.—Give any facts that you can as to the directions the earthquake waves seemed to travel. Describe the character of the shock, whether a temblor or an oscillatory motion, etc., and whether you, yourself, or others, had any clear impressions as to the direction in which it was moving, the facts on which this impression was based and whether people agreed as to the direction.

6.—Give also any further particulars of interest, whether they are from observation or hearsay. If any changes occurred in the ground, such as depressions or elevations of the surface, fissures, emissions of sand or water, describe fully. Character of damage to buildings. General direction in which walls, chimneys and columns in cemeteries were overthrown. Springs, wells and rivers are often notably affected, even by slight shocks, and any information in regard to such changes will be valuable.

7.—State as exactly as possible the *time of commencement* and the *duration* of each shock.

The exact time of the beginning of a shock (to the nearest second,) one of the most important of all observations, is difficult to get correctly, because of the great velocity with which the wave travels, and because the watch or clock must be immediately compared with a clock known to be keeping standard time. If several hours have elapsed before the comparison is made, another comparison should be made an hour later, in order to find whether your timepiece is gaining or losing. The observation cannot be regarded as a good one, unless it is stated that this has been done. Telegraph operators, railroad officials, watchmakers, etc., have especially good opportunities for answering this question correctly, and their co-öperation is most earnestly solicited.

If a clock was stopped, give the exact time it indicated (and anything known, as how fast or how slow it was,) its

position, the direction in which it was facing, and the length of the pendulum.

8.—If a shock was not felt in your neighborhood, although noticed at places not very far distant, do not fail to answer the first four questions, as negative reports are of great interest in defining the limits of the disturbed area, etc. State also the nearest point to your station where the shock was felt.

9.—Name the writer.

A. O. LEUSCHNER.

Berkeley, Cal., June 9th.

Secretary California State Earthquake Investigation Committee.

HEIGHT OF THE HYDROGEN FLOCCULI.

The first photographs of the Sun in hydrogen light were taken with the Rumford spectroheliograph of the Yerkes Observatory in 1903. The Hβ line was used. Upon developing the plate, Mr. ELLERMAN and I were surprised to find that instead of bright flocculi, similar to those obtained with the H and K lines of calcium, *dark* flocculi, of similar form, were present. Subsequent photographs showed that the hydrogen flocculi are ordinarily dark, though in the case of active eruptions, and sometimes in the immediate vicinity of Sun-spots, these flocculi are bright. With the Rumford spectroheliograph, it was possible to photograph only narrow zones of the solar image in hydrogen light, but with the spectroheliograph now in use with the Snow telescope on Mount Wilson, the entire solar disk is photographed daily with one of the hydrogen lines.

The darkness of the hydrogen flocculi was accounted for provisionally on the assumption that the regions shown are at a considerable elvation in the chromosphere, where the temperature is low enough to produce absorption. Independent evidence in favor of this idea has recently been afforded by the demonstration that the comparatively rare *dark* calcium flocculi are characterized by the widening of the H_3 and K_3 lines (due to the high level calcium vapor) and that these occasional dark calcium flocculi are almost invariably associated with very strong dark hydrogen flocculi. Some uncertainty as to the elevation of the ordinary dark hydrogen flocculi would still remain, however, since the exceptionally dark hydrogen flocculi just referred to might perhaps be at

a greater elevation. A new method of testing the question recently suggested itself to me and has been carried out with the aid of a Zeiss stereocomparator. In this instrument it is possible to observe, through a single eye-piece, (belonging to the new monocular micrometer attachment) a hydrogen plate superposed upon a calcium plate of the same date. The plates compared, are taken within so short an interval of time that no appreciable change occurs on the Sun between the exposures. The monocular eye-piece is provided with a device by means of which the light from either plate can be cut off, while the light from the other plate is admitted to the eye. The corresponding hydrogen and calcium flocculi can thus be observed in rapid succession, and the slightest relative displacement of their images can be detected and measured with the aid of the micrometer. Working in this way, especially near the Sun's limb, I found marked displacements of the hydrogen flocculi toward the limb. At the middle of the disk such displacements are almost entirely absent, though the observations are complicated by the fact that the hydrogen and calcium flocculi are not always identical in form. The results of a large number of measures of the relative positions of calcium and hydrogen flocculi leave no doubt in my mind, however, that the hydrogen flocculi, on the average, lie at a higher level, that the H_2 calcium flocculi. Such a difference of level would naturally cause displacements of the hydrogen flocculi with reference to the calcium flocculi, which should be in the direction of the limb and should increase with the distance from the center of the Sun. Such displacements are actually shown in the measures.

The method promises to be of considerable service, both in the comparative study of hydrogen and calcium flocculi, and in the investigation of differences of level of the calcium flocculi photographed with the H_1, H_2 and H_3 lines.

GEORGE E. HALE.

IDENTIFICATION OF FAINT LINES IN THE SPECTRA OF SUN-SPOTS.

In a recent paper by Mr. ADAMS and myself (*Contributions from the Solar Observatory*, No. 5), it was shown that the faint lines in the spectra of Sun-spots are coincident in position with the faint lines of the solar spectrum, though the solar lines are much fainter than the corresponding spot lines. Since most of these faint lines are not identified in Rowland's table of solar spectrum wave-lengths, the question of their identification was naturally raised. Mr. ADAMS and

Mr. GALE accordingly undertook a study of the subject in the laboratory, based upon the suggestion that long exposures of the arc spectrum might bring out many faint lines which are not given in published tables of wave-lengths. Such metals as titanium, vanadium and manganese, which are represented by many strong lines in the spectra of Sun-spots, were found to give numerous faint lines if the exposures were sufficiently prolonged. A large number of these lines have been identified with spot lines, precautions being taken to avoid mere chance coincidences. The investigation is being continued, and the spectra of all of the metals that are prominently represented in spot spectra will be studied in this way.

By the aid of photographic plates sensitized with pinachrome it has been found possible to obtain good photographs of the widened lines in the less refrangible region of spot spectra. The portion of the spectrum thus included in our regular work now extends from the red as far toward the violet as the widened lines are found.

GEORGE E. HALE.

ORGANIZATION OF THE COMPUTING DIVISION OF THE SOLAR OBSERVATORY.

The measurements of photographs taken on Mt. Wilson, and the necessary computations, will for the most part be made at the Solar Observatory Office in Pasadena. An addition to the building has recently been completed, with a number of offices for computers. The Computing Division will be in charge of Mr. W. S. ADAMS, who will hereafter spend much of his time in Pasadena, though he will continue to carry on special investigations at Mt. Wilson as opportunity permits. Miss LOUISE WARE, who was associated with Dr. SCHLESINGER in his investigation of stellar parallaxes at the Yerkes Observatory, under a grant from the Carnegie Institution, will join the Computing Division on July 1st. Other computers are being secured, and as several more will be needed in the near future, applications from persons desiring to take part in this work may be sent to Mr. ADAMS at the Solar Observatory Office, Pasadena. A new globe measuring machine for heliographic positions is just being completed, and measuring machines for spectra have been obtained from TOEPFER of Potsdam and GAERTNER of Chicago. Calculating machines have also been provided, and it is hoped that the Computing Division will be in full operation within a short time.

GEORGE E. HALE.

THE FIVE-FOOT REFLECTOR OF THE SOLAR OBSERVATORY.

The equatorial mounting of the five-foot reflector, which is under construction at the Union Iron Works in San Francisco, was not injured in the least by the earthquake. An erecting house, with electric hoisting apparatus capable of lifting loads of fifteen tons, has been provided on the grounds of the Solar Observatory in Pasadena. The reflector mounting will soon be erected in this house, and completed by our own instrument makers and machinists, working under the direction of Professor RITCHEY.

Excellent progress is being made by Professor RITCHEY and his assistants in parabolizing the five-foot mirror. A three-foot plane mirror is also being made for testing purposes. Other recent work of the optical shop includes a two-foot mirror of 143 feet focal length for the Snow telescope, a twenty-inch plane mirror for testing purposes, and several smaller plane and concave mirrors for laboratory use. The instrument shop is just completing the globe measuring machine for heliographic positions, a grinding machine for mirrors up to forty inches in diameter, a circular dividing engine, etc.

GEORGE E. HALE.

STABILITY OF THE THIRTY-SIX INCH EQUATORIAL OF THE LICK OBSERVATORY.

On Saturday, April 28th, Dr. J. H. MOORE and the writer, tested the adjustment in elevation of the 36-inch telescope by SCHAEBERLE'S method, and on the following Tuesday, May 1st, I determined the azimuth correction by observations on *Polaris*. The resulting corrections are:

1906, April 28th, level 44″ too low.

1906, May 1st, azimuth+60″

The last previous observations* for the position of the telescope were made by Professor SCHAEBERLE in 1896-97, with the results:

1896, December 5th, level 74″ too low.

1897, April 24th, azimuth+″

It is apparent from these figures that neither the recent great earthquake nor the sharp shock of August, 1903, has sensibly affected the position of the telescope. This result was expected since the telescope followed accurately in all parts of the sky after the earthquake, and determinations of parallel made east, west and south, agreed within the least reading of the micrometer position circle.

May, 1906. R. G. AITKEN.

*See these Publications, Vol. IX, p. 147, for summary of previous observations.

History of the Naming of Mt. Hamilton.

At the recent meeting of the National Academy of Sciences in Washington, I was pleased to secure from William H. Brewer, professor emeritus in Yale University, the history of the naming of Mount Hamilton. The following account is based on notes made by me during Professor Brewer's recital of the facts:

In the years 1853-4, Mr. Brewer, and Rev. Laurentine Hamilton, a Presbyterian clergyman, were intimate friends at Ovid, Seneca county, New York. About 1855, Mr. Hamilton went to Grass Valley, California, as a Presbyterian missionary, and a few years later he moved to San José, acting in the same capacity.

Mr. Brewer was a professor in Washington and Jefferson College during the years 1858-60. In the latter year Professor Brewer went to California to act as first assistant in charge of field work on the California State Geological Survey, then just established with Professor J. D. Whitney as State Geologist. Assistant Charles F. Hoffman was the Chief Topographer of the survey.

The work of Messrs. Brewer and Hoffman began at Los Angeles in November, 1860. They worked northward, reaching San José in May, 1861. From local reports, they judged that the mountain, thirteen miles due east of San José, was the highest within sight of San Francisco, and they were accordingly very anxious to occupy it as a point of observation in the survey. Brewer's friend, Hamilton, volunteered to accompany them to the summit, principally to show them the trails, with which he was familiar. This trip was made on horseback, nearly to the summit, probably to the point now known as the "brickyard," and the remaining distance was made on foot. Mr. Hamilton reached the summit first, and called back, "This is the top." Messrs. Brewer and Hoffman completed their observations and returned with Mr. Hamilton to San José.

Careful inquiry in San José and vicinity, and especially of the professors in Santa Clara College, established that the mountain had no name. It was known as the mountain or the *loma*.

At various times later in the year 1861, while Mr. Hoffmann was working up the map of the region, the naming of the mountain was discussed. Messrs. Brewer and Hoffman at first desired to call it Whitney, but Professor Whitney declined to let it be so called, holding that it was improper for the head of the survey to sanction it. Later in the same year, either Mr. Brewer or Mr. Hoffman suggested that the mountain be called Hamilton, in honor of Mr. Brewer's

friend, the Rev. LAURENTINE HAMILTON, and the name was thereupon adopted. Professor BREWER is not sure as to whether the suggestion came from him or from Mr. HOFFMAN.

W. W. CAMPBELL.

THE MEASUREMENT AND REDUCTION OF THE PHOTOGRAPHS OF EROS MADE WITH THE CROSSLEY REFLECTOR IN 1900.

The measurement and reduction of the photographs of *Eros* which were taken in 1900, with the Crossley Reflector, for the determination of the solar parallax, has been in progress at Mount Hamilton since December 1st, 1905. The work is being done by Miss FREDRICA CHASE, formerly of Vassar College Observatory and Miss ADELAIDE M. HOBE, formerly of the Students' Observatory of the University of California, under a grant from the Carnegie Institution.

Experimental measurements and reductions and the preparation of reduction tables for the entire work consumed about three months' time. The definitive measurement is now in progress and the measures of 150 plates are ready for reduction as soon as the places of the comparison stars are available.

The most serious difficulty in the reduction of this work was to obtain sufficiently accurate places of enough stars within the limited field of the Crossley plates. Through the kindness of Professor HINKS of the Cambridge Observatory, enough additional stars are being included in the catalogue, which he is forming for his own and other similar work, to satisfy this fundamental need completely.

May 19th, 1906. C. D. PERRINE.

NOTE ON A CONVENIENT METHOD FOR COMPUTING, FROM ELEMENTS, THE DAILY MOTION IN GEOCENTRIC RIGHT ASCENSION AND DECLINATION.

In Popular Astronomy for May, 1906, Professor HERBERT L. RICE, of the Naval Observatory gives a method of computing the daily motion in geocentric right ascension for an asteroid whose elements are given. After reading this it occurred to the writer to develop other formulae for determining this daily motion, based upon the methods used in LEUSCHNER'S "Short Method" for determining orbits. The same example that Professor RICE used to illustrate his method was used and shows that only about two-thirds as much computing is necessary as in his method.

As the daily motion in both right ascension and declination

are very useful in interpolating positions from an ephemeris, the writer suggests that hereafter such data be published along with an ephemeris. The extra computing necessary to obtain these for a four-date ephemeris would involve but very little time, not more than fifteen or twenty minutes. With this end in view, the formulae for obtaining the daily motion in geocentric declination and in $\log\rho$ have also been derived. The details of these developments have been forwarded to Popular Astronomy for publication.

June 11th, 1906. RUSSELL TRACY CRAWFORD.

THREE NEW RAPID BINARIES.

It is to be expected that many of the close double stars discovered at the Lick Observatory within the last few years, will prove to belong to the class of short period binary systems. In two instances, A 88 and A 417, this has already been demonstrated, my published measures showing a motion of 128° in five years for the former star, and of 33° in three years for the latter.

Measures made within the last few months show that Hu 1176, A 570, and A 691, also belong to this class. My recent measures and the discovery positions of these stars are as follows:

Hu 1176 = c *Herculis*.

1905.32	111.°7	0.″12	2n	HUSSEY.
1906.33	90. 4	0. 14	3n	AITKEN.
		A 570.		
1903.40	198.°6	0.″20	4n	AITKEN.
1906.32	172. 6	0. 23	2	"
		A 691.		
1904.48	226.°1	0.″11	3n	AITKEN.
1906.35	204. 2	0. 10	1	"

May, 1906. R. G. AITKEN.

THE DUPLICITY OF THE PRINCIPAL COMPONENT OF Σ 2348.

An examination with the 36-inch telescope on the night of May 17, 1906, showed that the principal component of the wide pair Σ2348 was itself, a very close double star. My measure

on that night made the distance only 0″.14 in the position angle 270°.5. The two components seem to be of the same brightness, each being rated at 6.0 magnitude. The Harvard Photometry gives the star, which is 190 *Draconis* B., the magnitude 5.4. Although the system possesses no sensible proper motion, it belongs to the type of stars in which rapid orbital motion is to be expected.

May, 1906. R. G. AITKEN.

NEW MEMBERS OF THE STAFF OF THE SOLAR OBSERVATORY.

Dr. HENRY G. GALE, recently Instructor in Physics at the Ryerson Laboratory of the University of Chicago, joined the staff of the Solar Observatory in February last. Dr. GALE'S principal work will be in the spectroscopic laboratory on Mount Wilson, where he is carrying on various investigations on arc and spark spectra as related to the spectra of Sunspots. For several years Dr. GALE has been assisting Professor MICHELSON in his optical investigations, and has thus acquired an experience which will prove of great service in his new work.

Dr. H. K. PALMER, who has recently returned from Chile, where he assisted Mr. WRIGHT in the spectroscopic work of the Mills Expedition of the Lick Observatory, has just joined the staff of the Solar Observatory. Dr. PALMER will for a time assist Mr. ABBOT in his studies of the solar constant, and subsequently take up bolometric investigations of the Sun with the Snow telescope. His acquaintance with reflecting telescopes, derived from his work with the Crossley reflector, as Professor KEELER'S assistant, and his subsequent work in South America should render him a valuable member of our staff. GEORGE E. HALE.

PERSONAL NOTES.

Mr. SEBASTIAN ALBRECHT, fellow in the Lick Observatory during the past three years, received the degree of Doctor of Philosophy, in Astrophysics, at the May commencement of the University of California. The titles of his theses are:

1. A Spectrographic Study of the Fourth Class Variable Stars Y *Ophiuchi* and T *Vulpeculae*.

2. On the Distortion of Photographic Films on Glass.

During the coming academic year, Dr. ALBRECHT will be an assistant in the Lick Observatory, on the D. O. Mills foundation, continuing the measurement and reduction of spec-

trograms obtained by the Mills Expedition to the Southern Hemisphere.

Mr. GEORGE F. PADDOCK, post graduate student in the McCormick Observatory, University of Virginia, has been appointed assistant in the Lick Observatory, with duties at Santiago, Chile, assisting Astronomer HEBER D. CURTIS, in charge of the Mills Expedition. Mr. PADDOCK sails from New York on June 30th.

Dr. HAROLD K. PALMER, successively Fellow in the Lick Observatory and Assistant on the D. O. Mills foundation in Chile, and on Mount Hamilton, has resigned to accept a position on the staff of the Solar Observatory of the Carnegie Institution on Mount Wilson. Dr. PALMER goes with the good will and best wishes of all the residents of Mount Hamilton.

Mr. ROSCOE F. SANFORD, B.S., University of Minnesota, 1905, has been appointed as Carnegie Assistant in the Lick Observatory, with duties in the Meridian Circle Department, under Professor TUCKER's direction.

W. W. CAMPBELL.

SMITHSONIAN EXPEDITION TO MOUNT WILSON.

Mr. CHARLES G. ABBOT, Aid acting in charge of the Smithsonian Astrophysical Observatory, has arrived at Mount Wilson, and will continue the study of the solar constant which he commenced here last year. During the winter the numerous bolographs and pyrheliometer measures made last summer have been reduced at Washington, with extremely satisfactory results. In view of the high precision of these determinations of the solar constant, due to the excellence of the atmospheric conditions at Mount Wilson, it is hoped that the Smithsonian Institution will be able to continue this work through at least one full Sun-spot period.

GEORGE E. HALE.

AWARD OF THE DRAPER MEDAL TO DIRECTOR CAMPBELL.

The National Academy of Sciences has this year conferred the Draper Medal upon Dr. W. W. CAMPBELL, Director of the Lick Observatory. The medal was formally presented to Dr. CAMPBELL on April 17th, at a banquet given by President ALEXANDER AGASSIZ, to the members of the Academy and invited guests in Washington, D. C.

R. G. AITKEN.

GENERAL NOTES.

PRIZES OFFERED BY THE FRENCH ACADEMY OF SCIENCES.

The sum of 100,000 francs has been bequeathed by Madame GUZMAN to the French Academy of Sciences as a prize, to bear the name of the PIERRE GUZMAN Prize, in memory of her son, and to be awarded to one who shall discover means of communicating with some astral body other than the planet *Mars*. Forseeing that this prize will probably remain unclaimed for some time to come, provision has been made that the accumulating interest shall be used for prizes, also bearing the name PIERRE GUZMAN, to be awarded at intervals of five years to scholars, either French or foreign, who shall make important contributions to the Science of Astronomy. The year 1910 has been fixed upon as the date for the first award.

Other prizes offered by the Academy are: The LALANDE Prize (annual,) of 540fr. for the one making the most interesting observation or publishing the memoir most useful to the progress of astronomy.

The VALZ Prize (annual,) of 460fr. for the most interesting astronomical observation.

The G. DE PONTECOULANT Prize of 700fr. (biennial) to encourage researches in Celestial Mechanics, to be awarded in 1907.

The DAMOISEAU Prize of 2000fr. (triennial,) to be awarded in 1908, for a theory of the planet *Eros*, based on all known observations.

The JANSSEN Prize of a gold medal (biennial,) to be awarded in 1908, for a discovery or research embodying important progress in physical astronomy.

THE PRESSURE OF LIGHT. The Friday evening lecture at the Royal Institution last week was given by Professor J. H. POYNTING, whose subject was "Some Astronomical Consequences of the Pressure of Light." The lecturer said that the pressure of light—or rather of the whole range of radiation from the infra-red to the ultra-violet—which had been predicted by CLERK MAXWELL and proved to exist by the experiments of NICHOLS and HULL and of LEBEDEW, constituted a new force that had to be reckoned with. Though apparently negligible in terrestrial affairs—the pressure on the Earth would amount to some 75,000 tons, which was a mere

nothing in comparison with the gravitational pull of the Sun —it might have considerable importance out in the solar system in regard to bodies which, though smaller than our planet, were yet much larger than those which composed the tails of comets. He considered a beam of light as a carrier of momentum, bearing with it a forward push which it was ready to impart to any body on which it impigned, and exerting a backward push on the source from which it had been radiated. He discussed the effects that arose on the supposition that either the source or the receiving surface was in motion, and examined the conditions, as to size and distance, in which the gravitational pull on masses of matter would be outbalanced by the pressure of the Sun's radiation. Taking the case of a comet, regarded as composed, to begin with, of a compact cloud of particles of various sizes, he pointed out that the coarser particles, as the comet revolved round the Sun, would get in front and the finer trail behind. After several hundred revolutions the finer dust would have drifted nearer the Sun, and, given time, the different sizes might become so scattered as to lose all appearance of connection with each other. There could be no doubt that this effect existed, if comets had the constitution they were now supposed to have, and its result must be that a comet would in time, undergo dissolution and ultimately end in the Sun. *The Times* of May 14th, 1906.

NEW ASTRONOMER ROYAL OF IRELAND. Following closely upon the appointment of Mr. F. W. DYSON to the post of Astronomer Royal for Scotland and Professor of Astronomy, comes that of Mr. E. T. WHITTAKER to a similar position in the sister island. As the writer of the "Oxford Note Book" points out, both Mr. DYSON and Mr. WHITTAKER held the Sheepshanks Astronomical Exhibition, Mr. WHITTAKER also an Isaac Newton Studentship, while Trinity College, Cambridge, numbers among its Fellows the Royal Astronomers of these three kingdoms.—*Journal of the British Astro. Association.*

The following notes have been taken from recent numbers of *Science*:

Rear-Admiral COLBY M. CHESTER, superintendent of the U. S. Naval Observatory, was placed on the retired list on February 28th. He will be retained in temporary active duty in the Bureau of Navigation. Rear-Admiral CHESTER will be succeeded in charge of the Naval Observatory by Rear-Admiral ASA WALKER.

Professor E. C. PICKERING, director of the Harvard Col-

lege Observatory, has been elected a corresponding member of the Berlin Academy of Sciences.

Professor JAMES MILLS PEIRCE, who was appointed tutor in Harvard University in 1854, and has been Perkins professor of astronomy since 1885, died from pneumonia at his home in Cambridge on March 21st.

Mr. FEE writes, in a consular report, that the new standard time for India was adopted in Bombay, on January 1st, and is gradually overcoming the prejudice incident to a new departure. He further says: "The Indian standard time is in advance five hours and thirty minutes of Greenwich time, being nine minutes faster than Madras time, about twenty-four minutes slower than Calcutta time, and about thirty-nine minutes faster than Bombay local mean time, the longitude of the city of Bombay being 72° 52′ east of Greenwich. Five hours and thirty minutes advance of Greenwich time would be the local mean time for longitude 82° 30′ east of Greenwich. This parallel of longitude passes through India at about the eastern mouth of the Godavery River in the Bay of Bengal, and near Benares, the sacred city of the Hindus, on the Ganges River. It is the local mean time of this parallel that now sets the standard of time for all India."

Dr. ANDING, professor in the University of Munich, has been appointed director of the observatory at Gotha.

Dr. PAUL GUTHNICK, of Bothkamp, has been appointed astronomer in the Royal Observatory at Berlin.

The next meeting of the Astronomical and Astrophysical Society of America, will be held at New York, in affiliation with the American Association for the Advancement of Science, during convocation week, 1906-7.

The *Observatore Romano* officially announces that the Rev. JOHN GEORGE HAGEN, director of the observatory at Georgetown University, is in Rome, and will be appointed director of the Vatican Observatory.

Dr. JOHN ANTHONY MILLER, professor of Mechanics and Astronomy, in Indiana University since 1895, has resigned in order to accept the professorship of Mathematics and Astronomy in Swarthmore College.

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS, HELD AT THE FACULTY CLUB, UNIVERSITY OF CALIFORNIA, BERKELEY, SUNDAY, MAY 20, 1906, AT 3:30 P. M.

President LEUSCHNER presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected.

ELECTION.

Professor HEBER D. CURTIS, Casilla 1219, Santiago, Chile.
Mr. J. WALTER MILES, Irwin, Pennsylvania.
Dr. J. H. MOORE, Lick Observatory, Mount Hamilton, California.
Mr. W. P. RUSSELL, Pomona College, Claremont, California.
Mr. GEORGE W. SPENCER, 458 Ninth street, Oakland.

The secretary reported that the personal property of the society, including its entire library, pictures, furniture and archives, contained in its rooms in the California Academy of Sciences Building, 819 Market street, was totally destroyed by the conflagration of April 18th, 1906. The funds of the society, consisting of investments aggregating $15,959.54, are all intact, as well as a supply of the *Publications*, stored at the Lick Observatory.

The following resolutions were adopted:

Resolved, that the *Publications* of the society be continued as usual.

Resolved, that the *Publication* No. 107 which was in press at the time of the fire, be reprinted.

Resolved, that the Publication Committee be allowed to expend $700 for *Publications* (including No. 107,) to the end of December, 1906.

Resolved that the Finance Committee be instructed to provide the funds necessary to meet the obligations of the society, by drawing upon such funds as they may deem advisable.

Resolved that the President and Library Committee be authorized to prepare a circular regarding the loss of the society's library, to be sent to such institutions and persons as they may select.

Resolved, that a meeting of the society be held at the Lick Observatory on the last Saturday of September.

Resolved, that the invitation extended to the society by the President of the University of California, to make the Students' Observatory at Berkeley, the temporary headquarters of the library of the society, be accepted, and the grateful thanks of the Board of Directors be returned to President WHEELER for his courteous offer.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE STUDENTS' OBSERVATORY AT BERKELEY, ON SATURDAY, JUNE 9, 1906, AT 8 P. M.

The society was called to order by President LEUSCHNER, who introduced as lecturers of the evening, Professor F. OMORI of the Imperial University of Tokio, Japan, who presented a paper on Observations of Distant Earthquakes, and Professor A. C. LAWSON, of the University of California, who spoke more particularly of the California Earthquake of April 18th, 1906.

After the conclusion of the addresses, the observatory buildings were opened for the inspection of members and visitors.

OFFICERS OF THE SOCIETY.

Mr. A. O. Leuschner.....President
Mr. Chas. S. Cushing.....First Vice-President
Mr. A. H. Babcock.....Second Vice-President
Mr. W. W. Campbell.....Third Vice-President
Mr. R. G. Aitken }
Mr. F. R. Ziel..... } .....Secretaries
Mr. F. R. Ziel .....Treasurer

Board of Directors—Messrs. Aitken, Babcock, Burckhalter, Campbell, Crocker, Cushing, Hale, Leuschner, Richardson, Spreckels, Ziel.
Finance Committee—Messrs. Cushing, Crocker, Richardson.
Committee on Publication—Messrs. Aitken, Townley, Newkirk.
Library Committee—Mr. Von Geldern, Mr. Richardson, Mrs. Schild.
Committee on the Comet-Medal—Messrs. Campbell (ex-officio), Burckhalter, Perrine.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the Publications for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the Publications of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the Publications is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the Publications should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communictaed to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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VOL. XVIII. SAN FRANCISCO, CALIFORNIA, AUGUST 10, 1906. No. 109.

ON SEISMIC MOTION AND SOME RELATIONS OF EARTHQUAKES TO OTHER PHENOMENA.[1]

BY F. OMORI.

Earthquake.—An earthquake consists, as the name signifies, in the trembling of the ground, and may be defined as vibrations or wave-movements propagated through rocks and soil, the motion diminishing with the increase of the distance from the source of disturbance. The magnitude or energy of an earthquake, taken as a whole, may be represented by the area within which the motion is felt; while the intensity of motion at a given place, which depends on the size of the earthquake, decreases in an inverse proportion to the distance. Thus, according to the depth of the earthquake center, there may be large disturbances in which the motion at the surface is not extremely violent, as well as small ones, in which the motion is quite severe.

Disturbance of Waters.—When the earthquake motion of inland origin is large and violent, the waters of ponds, rivers, or lakes are more or less disturbed. So, similarly, a great submarine earthquake is often followed by tidal waves; the time interval between the occurrence of the earthquake shock and the arrival of the sea-waves depending on the depth of the water and the distance of the origin from the shore. The tidal waves following the great Japan earthquake of December 23, 1854, which wrecked the Russian frigate "Diana," then at anchor in the harbor of Shimoda, crossed the Pacific, and were recorded by the tide-gauges at San Francisco and other places on this coast of America.

[1] Read June 26, 1906, before an adjourned meeting of the Society. Abstracted by A. O. LEUSCHNER.

Tidal waves, which are not to be noticed on the high sea, are developed most markedly on indenting bays with shallow waters. Many of the great earthquakes originating off the Pacific coast of Alaska and Central and South America have been accompanied by large tidal waves. But fortunately this phenomenon, which sometimes causes more damage than the earthquake disturbance itself, has so far not been very active along the coast of the United States. The great earthquake of April 18th last produced distinct but very small disturbances of the bay waters, which were clearly recorded by the tide-gauge at the Presidio. An examination of the marigrams at several stations on the Pacific Coast of Japan and different places in India has shown that different parts of seacoast have their proper period or periods of waves,—that is to say, each particular portion of seacoast is virtually a fluid pendulum whose boundaries are determined by the form of the bottom and the contour of the shore-line. Accordingly, the wave period or periods at a given coast place remain constant in all the tidal waves, irrespective of the origin or cause, a destructive tidal wave consisting simply in the amplification of the wave motion *existing more or less at all times*, in consequence of a strong submarine earthquake, a storm, or some other agency. A seismic tidal wave is caused by the movements communicated from the sea-bottom to the water mass, a very large wave disturbance taking place when the earthquake focus is at the sea-bottom itself or at a very small depth below it.

Dependence of Earthquake Motion on Nature of Ground.—As an earthquake consists in the vibration of the ground, and the range of motion, or amplitude, of an earth particle is greater in a soft than in a hard medium, it is evident that the intensity must depend much on the nature of the ground, often differing considerably even within a limited area. The seismic damage is always very slight on hard, rocky ground, and severest on soft, incoherent soil, and especially on newly made ground. From this fact it will be seen at once that the foundation-making plays a most important part in the earthquake-proof construction of buildings and engineering structures. By making the foundation large and solid we approach the condition of a rocky ground. If the foundation be, on the other hand, small and weak, the structure resting on it

will be virtually a group of different bodies loosely bound together, and will be thrown into large movements, causing a mutual destruction. As the length of the elastic or proper earthquake waves constituting a destructive shock must be about two to three miles, the slight curvature into which the ground surface is thrown on such occasions will not be evident to the eye. It seems, however, that in a soft, marshy soil a violent earthquake sometimes produces, as a secondary phenomenon, a sort of semi-gravity vibration of short wave-lengths, say about twenty or thirty yards. The latter motion, which will be visible to direct observation, and which may be called "visible surface motion," often throws the ground into remarkable curved forms and is very dangerous to structures. But injurious effects of this sort can be entirely avoided by making the foundation of a structure sufficiently large and solid, thereby reflecting back the disturbance consisting of short wave-length vibrations. The case is analogous to the effect of water-waves on bodies floating on the surface. Thus a small fragment of wood or straw behaves as if it were a particle of the water and moves together with the small ripples; but a large vessel at anchor in a harbor will not be affected by the waves on account of its mass and size.

It may be noted that high ground is, except sand-dunes, generally hard, and therefore good as the site for buildings. But a steep slope or the vicinity of a cliff must be avoided, as the earthquake motion is in such places considerably augmented, owing to the absence of support on the side.

Tremors and Pulsatory Oscillations.—We are accustomed to regard the Earth as solid and firm. But it is a great mistake to suppose that the ground is at rest when we do not *feel* an earthquake. As the Earth's crust is an elastic body, we must assume, in a general way, that it is always making some movements. And so it does in reality, there being besides the tilting or inclination of the ground-level three principal sorts of vibratory movements, as follows: (1) Tremors of artificial origin; (2) Small, slow motions, called pulsatory oscillations; (3) Earthquakes.

Among the insensible tremors of an artificial origin I may mention those due to the working of dynamos, steam-engines, steam-hammers, etc. The motion produced by such causes is extremely small, and is generally, except in the immediate

vicinity, insensible. It is transmitted, however, sometimes to a distance of half a mile or more, and sets different objects in unstable conditions, so to speak, spontaneously in motion. Thus windows and doors are caused to rattle, bottles on tables to shake, suspended articles to swing, etc., becoming a source of mystery to people in the neighborhood and even giving rise to rumors of ghosts.

Causes of Earthquakes.—The ultimate causes of great earthquakes are probably to be traced to the cooling and contraction of the Earth, and in some degree to the change of distribution of the matter constituting the land and ocean-bottom. The more immediate cause of such earthquakes is, however, frequently due to the activity of mountain-making forces which produce folding or fracturing along extended zones; and any sudden disturbance in the Earth's crust, such as the splitting asunder, fracturing, or falling down of subterranean rock masses, may become the source of earthquake motion. Different external agencies which act on the Earth, and many of which are periodic, may be regarded as secondary causes of earthquake. Thus it will be seen that seismic phenomena, which are themselves periodic in nature, must have certain time and space relations.

After-Shocks.—Numerous small shocks invariably follow a great earthquake. When the latter is violent and destructive the number of these after-shocks may amount to hundreds, or even thousands, and continue for several months or several years. The occurrence of after-shocks is quite natural and necessary for the settling down into stable condition of the disturbed tract at or near the origin of the initial earthquake. Now, the mean time variation of after-shocks follows a very simple law, and analytically may be represented by means of a rectangular hyperbola. In the case of the great Japanese earthquakes of 1891, I calculated an empirical formula from the number of after-shocks observed during the first five days after the initial disturbance, and was enabled thereby to predict the general course of subsequent phenomena, such as the number of years during which these shocks should continue to happen, the total number of after-shocks from beginning to end, or the number of after-shocks during a certain year. Similar calculations have been made, with equally satisfactory results, for the after-shocks of other recent

Japanese earthquakes. Examples like these show that earthquake phenomena, though apparently mysterious, are not always so very complicated and arbitrary. In the case of the California earthquake of April 18th last, the after-shocks seem to be comparatively very few for some reason or other. These minor shakings, which will continue to happen at intervals for a few years to come, are of course harmless in nature.

Time relations of earthquakes may be distinguished as periodic and semi-periodic. Among the latter class may be included destructive earthquakes which tend to occur in groups,—that is to say, to happen in different regions of a given earthquake zone in the course of a few years. Then there follows a period of rest, after which the seismic activity again commences.

The most well-marked among the periodic seismic variations are those relating to the position of the Sun and the Moon. Thus there are annual variations in the number of earthquakes,—namely, earthquakes occur more frequently in certain months of the year than at others. So again there are more earthquakes during certain hours of the day than during others. The direct principal cause for these variations is, however, not the attraction of the Sun, but the changes in the pressure of the atmosphere. This is in reality the connection between the weather and earthquakes, although the so-called "earthquake weather," or a warm or moist day, is by no means a sure precursor of tremblings of the ground. On the contrary, the high barometric pressure corresponding to fair weather seems to bring more earthquakes when the latter are not of a submarine origin. Again, the study of after-shocks has shown clearly the existence of other periods whose lengths are respectively twelve, eight, six, and four hours, and also those whose periods are four or five days, eight or nine days, twelve days, etc.

With respect to the lunar influence, there are certain relative positions of the Earth and the Moon at which more earthquakes take place than at other positions. This effect is again not due to the direct attraction of the Moon, but to the variation of the weight of water in the tidal movements. The annual, diurnal, lunar, and some other relations of earthquakes must be treated separately for each given district so as to bring out the local peculiarity.

The attraction of the planets on the Earth will have no appreciable effect on earthquake phenomena.

Latitude Variation.—Apart from the earthquake movements, pulsatory oscillations, and slight changes in the ground-level, the axis of rotation of the Earth is continuously shifting its position through a very small angle, giving rise to the variation of latitude. Professor MILNE and the late Dr. CANCAIN were the first to examine the relations between this phenomenon and great earthuakes, the conclusion reached being that a greater number of the latter occurred in those years in which the variation of latitude was greatest. From an examination of the mean monthly values of the latitude of Tokyo, I have found that all the destructive earthquakes of recent years in Japan occurred exactly or very nearly when the latitude was at a maximum or minimum.

Magnetic Disturbances.—As the magnetic property of rocks and metals varies with the strains to which they are subjected, a great earthquake, which means the removal of an enormous stress in the Earth's crust, may be supposed to be preceded or accompanied by some disturbances in the terrestrial magnetism, at least when the depth of the seismic origin is small. The relation in question has not yet been satisfactorily investigated, but in some cases the terrestrial magnetism which had been quiet for a long time became markedly disturbed a few days before a large earthquake. In this connection, it is interesting to note that the great eruption in Martinique was accompanied by a well-defined magnetic disturbance.

Geographical Distribution of Earthquakes.—In the first place, a country or district which has many volcanoes is one where the Earth's crust is weak, and consequently is often disturbed by underground convulsions or earthquakes. It does not follow, however, that earthquakes are most frequent around a volcano. On the contrary, the immediate vicinity of a great active volcano is sometimes free from very violent seismic disturbances. Broadly speaking, strong or extensive earthquakes most frequently happen along the region adjacent to the steep sides of a great mountain range or of a series of islands. The variation of gravity in an earthquake country may also have something to do with earthquake geography, and there are cases in which destructive shocks have occurred in the district of a minimum gravity force.

Future studies in various phenomena connected with the movements of the Earth's crust may perhaps tend to advance our knowledge respecting the problem of the prediction of great earthquakes which are often preceded by what may be called "fore-shocks." In the mean time and always it will be necessary to build houses and other structures strong enough to resist earthquake shocks.

SAN FRANCISCO, June 26, 1906.

THE LATITUDE OF UKIAH BEFORE AND AFTER APRIL 18, 1906.

BY SIDNEY D. TOWNLEY.

After investigation had shown that the earthquake of April 18th was caused by horizontal shearing along a geological fault running in nearly a straight line from the vicinity of San Juan, in San Benito County, to near Point Arena, in Mendocino County, and that relative displacements along the line of fault had been found, amounting, in one instance at least, to as much as twenty feet, the question naturally arose, Have the latitudes and longitudes of places near the fault-line been disturbed in a measurable degree?

The International Latitude Observatory at Ukiah, where continuous observations for the variation of latitude are made by the writer for the International Geodetic Association and under the superintendence of the United States Coast and Geodetic Survey, is situated about twenty-six miles to the east-northeast of the point where the fault-line enters the Pacific Ocean near Point Arena. That a displacement of a measurable amount could have taken place at that distance from the fault-line seemed highly improbable, but an approximate reduction of all the observations for latitude made on April 16th, 17th, 18th, and 19th showed an apparent displacement of three feet to the south. On account of the small number of observations involved and the approximate nature of the reductions, this apparent shift could not be looked upon as certainly real.

As these computations did not settle the matter one way

or the other, it seemed desirable to make further computations, and consequently all of the observations for latitude, 233 in number, obtained between April 4th and May 4th, both inclusive, have been definitively reduced, and the results are pre-

TABLE I.

		GROUP VI.								GROUP VII.								GROUP VIII.							
	Pair....	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
1906, April	4	2.31	1.96	1.79	2.15	1.81	2.14	2.25	3.12	1.92	1.95	2.20	1.64	2.41	2.24	1.93	2.31	1.93	1.85	....	....	....	....	....	....
	5	2.24	1.65	1.75	1.93	1.74	2.61	1.87	2.76	2.04	1.86	2.18	1.73	2.15	2.15	2.01	2.27	2.22	1.80	2.27	1.87	2.00	1.89	2.14	1.87
	7	2.25	1.41	2.01	2.37	1.72	2.08	2.01	2.71	2.17	1.73	2.35	1.90	2.24	2.24	2.05	2.60	2.25	2.53	2.46	1.91	1.80	1.86	2.45	2.19
	10	1.93	1.45	1.98	2.02	1.87	2.26	2.03	2.83	2.11	1.89	1.96	1.48	1.88	2.17	2.09	2.36	2.04	1.79	2.50	1.39	1.66	2.08	2.37	2.15
	11	1.57	1.74	1.53	2.29	1.82	2.30	1.92	2.72	2.21	1.97	2.07	1.75	2.24	2.07	1.77	2.55	2.14	....	2.38	1.67	1.77	2.08	2.08	1.77
	12	1.98	1.57	1.65	1.99	2.16	2.41	1.95	2.72	1.90	1.92	2.09	1.52	2.23	1.87	1.89	2.35	2.08	2.14	2.58	1.48	1.83	1.86	1.95	1.83
	13	2.15	1.79	1.87	1.90	1.90	2.11	2.17	2.90	2.02	2.27	1.91	1.68	2.11	1.98	2.01	2.32	2.18	1.90	2.29	1.91	2.16	1.67	2.14	1.75
		GROUP VII.																							
	Pair....	49	50	51	52	53	54	55	56																
1906, April	16	2.18	2.21	2.22	1.72	2.08	2.05	2.27	2.38																
	17	2.01	2.30	2.07	1.92	2.09	1.77	2.28	2.57																
	18	2.05	2.15	2.46	1.89	2.08	2.04	1.87	2.13																
	19	1.97	1.84	2.06	1.76	1.99	2.14	2.06	2.62																
	25	2.04	2.12	2.03	1.38	2.07	1.99	1.66	2.35																
	30	1.91	2.16	2.39	1.45	2.16	2.19	1.95	2.60																
	33	2.03	2.61	1.86	1.64	2.01	2.11	2.11	2.32																
	34	2.38	1.80	2.28	1.42	1.98	2.31	2.09	2.65																

sented in Table I, which gives the individual values of the latitude — 39° 8′ 10″. All corrections, level, differential refraction, curvature of the parallel, and progressive errors of the micrometer-screw have been taken into account, and the observations were reduced by means of the declinations furnished by the International Geodetic Association.

A cursory inspection of the results given in Table I shows that the values, especially for certain pairs, are affected by errors of declination of considerable magnitude, and unless steps are taken to eliminate these errors the quantity sought may be completely masked by them. All of the observations for the variation of latitude obtained from the time work began in 1899 to the end of 1905 were made upon the same pairs of stars, and the observations have been reduced with declinations rendered homogeneous by a system of corrections derived from the observations made during the first two years of this time. At the beginning of 1906, however, thirty out of the total of ninety-six pairs were replaced by new ones, and of course a system of homogeneous declinations has not yet been obtained. It will probably be well along in the year 1908 before this can be gotten.

It is obvious from these considerations that a discussion of the results presented in Table I is beset with difficulties, although these are not entirely insurmountable. Four different methods have been used in combining the results, and these are presented under the following heads:—

I. The simplest and most obvious way of eliminating the errors of declination is to consider only those pairs which were observed both before and after April 18th. Group VII, pairs 49 to 56, was observed on nine dates preceding and six dates following April 18th, and the simple means give the following results for the latitude of the zenith telescope:

1906, April 11	39°	8′	12″.070	± 0″.012	72 pairs
1906, April 26	39	8	12 .066	± 0 .019	48 pairs

If we take these results only to hundredths of a second, which is perhaps all we are warranted in carrying, it is seen that they are exactly the same. The probable error of a single determination of the latitude in the first series is 0″.103, in the second 0″.131. The first of these is about normal, and the largeness of the second may be due to the fact that since

there are only six observations of each pair in this series, the computed error is itself somewhat uncertain. It will be noticed that the residuals for pair 50 are abnormally large, which is due in all probability to the fact that the first star of this pair is of the 4.5 magnitude and two magnitudes brighter than the second star of the pair. With the instrument employed, it is extremely difficult, especially when the seeing is not first-class, to make accurate settings upon stars brighter than the fifth magnitude.

II. If we consider only the twenty-six observations made upon April 16th and 17th and the observations of the same pairs on April 18th and 19th, in which case consideration of the known variation of the latitude may be neglected, we have:—

1906, April 16.5	39° 8′ 12″.076	26 pairs
1906, April 18.5	39 8 12 .084	26 pairs

Here again the results are identical if taken only to hundredths of a second. On account of the errors of declination involved, it is not possible in this case to compute probable errors.

III. Pairs 42, 45, 46, 48, 52, 56, 59, and 60 are new ones, introduced at the beginning of 1906. If we leave them out of consideration, the resulting means from the other pairs are:—

1906, April 11	39° 8′ 12″.039	90 pairs
1906, April 26	39 8 12 .050	71 pairs

This result, in almost exact agreement with that obtained under II, is obviously open to the criticism that although the declinations of the pairs used in forming the means *belong* to a homogeneous system, yet they form only a *part* of that system, and if we could include the other pairs of the system the result might be changed in some slight degree.

IV. The three methods thus far employed are all open to the fundamental objection that they do not utilize all of the material at hand. In order to do this a system of corrections to the declinations, or to the values of $\frac{1}{2}(\delta_n + \delta_s)$, must be computed, and for this purpose the following methods were employed.

(a) On each night that a complete set of latitude observations was obtained the mean of the sixteen individual values was taken.

(b) With these means the residuals were formed for the individual observations. These residuals are made up of two parts, the accidental errors of observation and the errors of declination referred to a mean declination system of the two groups involved.

(c) The residuals for each pair were collected and the means taken in order to eliminate the accidental errors, and the results are then the corrections to $\frac{1}{2}(\delta_n + \delta_s)$.

(d) By this process two series of corrections to $\frac{1}{2}(\delta_n + \delta_s)$ for the pairs of Group VII were obtained,—first, the corrections referred to the mean-declination system of the group connection VI-VII, and, second, the corrections referred to the mean-declination system of the group connection VII-VIII. These corrections were found to differ appreciatively, and in order to bring them into one homogeneous system all of the corrections for the pairs in series VI-VII were changed by $-0''.020$ and all of those in series VII-VIII by $+0''.024$, thus making the two series of corrections to the pairs of Group VII fulfill the condition that the algebraic sums of these corrections should be equal. The weighted means of the individual values of the corrections in these two series were then taken as the final corrections to the pairs of Group VII. The following table of corrections was thus found:—

TABLE II.

r...	41	42	43	44	45	46	47	48
Corr.	$-0''.019$	$+0''.390$	$+0''.246$	$-0''.050$	$+0''.183$	$-0''.230$	$+0''.014$	$-0''.780$
Pair...	49	50	51	52	53	54	55	56
Corr.	$+0''.007$	$+0''.023$	$-0''.083$	$+0''.386$	$-0''.059$	$-0''.036$	$+0''.054$	$-0''.373$
Pair...	57	58	59	60	61	62	63	64
Corr.	$-0''.018$	$+0''.067$	$-0''.283$	$+0''.372$	$+0''.162$	$+0''.151$	$-0''.111$	$+0''.161$

(e) Applying the corrections of Table II to the results given in Table I we have, taking the means before and after April 18th:—

1906, April 11	39° 8′ 12″.051	138 pairs
1906, April 26	39 8 12 .068	95 pairs

The method of procedure outlined above is to a certain extent empirical, and, especially on account of the small amount of data involved, it is admittedly open to certain criticisms. That the result obtained is in practical agreement with those given by the three preceding methods must be

considered, at least to a certain extent, as fortuitous. No entirely satisfactory discussion of the results presented in Table I can be made until a homogeneous system of declination corrections has been obtained, and sufficient material from which to form such a system will not be at hand for at least two years.

In considering the results obtained under I, III, and IV we must take account of the known variation of the latitude. The earthquake came about seven weeks after a minimum of the latitude at Ukiah, and from the normal curve for the variation of latitude we find that at seven weeks after a minimum the latitude should be increasing at the rate of about 0″.02 in half a month.

Collecting the results we have:—

	Observed variation.	Computed variation.	O − C
I	−0″.00	+0″.02	−0″.02
II	+0 .01	+0 .00	+0 .01
III	+0 .01	+0 .02	−0 .01
IV	+0 .02	+0 .02	0 .00
Mean,			−0″.005

If real, this would show a shifting of the observatory one half foot to the south. An inspection of the probable errors given under I shows, however, that this result is less than the probable errors of the quantities from which it is determined.

The computations show, and I think conclusively, that there was on April 18th no shifting of the Earth's crust at Ukiah, at least none of sufficient magnitude to be certainly differentiated from the accidental errors of observation in the most refined method which we have for the determination of latitude. A shifting of four feet, and probably of three, would certainly have been revealed by the observations.

July 6, 1906.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1906.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon...	Sept. 2,	3h 36m	P.M.	Full Moon.....	Oct. 2,	4h 48m	A.M.
Last Quarter.	" 10,	12 54	P.M.	Last Quarter...	" 10,	7 39	A.M.
New Moon...	" 18,	4 33	A.M.	New Moon.....	" 17,	2 43	P.M.
First Quarter	" 24,	10 11	P.M.	First Quarter...	" 24,	5 50	A.M.
				Full Moon.....	" 31,	8 46	P.M.

The Sun crosses the equator from north to south and autumn begins September 23, about 3 P. M., Pacific time.

Mercury on September 1st is a morning star, rising a little more than an hour and one half before sunrise. It passed greatest west elongation (18° 12′) on September 29th, and soon begins to approach the Sun quite rapidly. It can be seen quite well for the first few days of the month, but the period of visibility is short. The greatest elongation is smaller than the average, as the planet passes its perihelion point on September 4th. *Mercury* reaches superior conjunction with the Sun on September 24th and becomes an evening star. This condition lasts until the end of November, but the planet's position south of the Sun makes the interval between the setting of the Sun and of the planet increase very slowly, and it will not be as great as one hour until after the end of October. A very close conjunction with *Mars* occurs on September 4th, while *Mercury* is in fine position for early-morning observation. The nearest approach of the planets is 9′, less than one third of the diameter of the Moon, but both are below the horizon for all parts of the United States at this time. However, they will be seen quite close together on the mornings of September 4th and 5th.

Venus is an evening star, and throughout the two months sets rather less than two hours after sunset, the interval remaining almost constantly $1^h\ 41^m$ until after the middle of October. It then begins to shorten, and by the end of the month is less than an hour and one half. *Venus* reaches its greatest east elongation from the Sun on September 20th, its distance then being 46° 29′. It passed its aphelion on September 17th, but the orbit of the planet is so nearly circular

that there is very little difference between greatest elongations, the varying distance of the Earth from the Sun at the times of greatest elongation having more influence than the position of the planet in its own orbit. The planet soon begins to approach the Sun quite rapidly, and by the end of October the distance is only 36°. *Venus* has now reached the part of its orbit where it is nearer to the Earth than to the Sun, and shows a crescent shape in the telescope. Its diminishing distance causes a great increase in brightness, and this lasts until the time when the planet is about halfway between greatest elongation and inferior conjunction. This occurs on October 25th. After that the narrowing of the crescent as the planet nears the Sun causes some diminution in brightness, although the distance keeps on diminishing until conjunction. The planet will be visible to the naked eye in full sunlight for a fortnight or so before and after the time of greatest brightness.

Mars is a morning star, rising a little more than an hour before sunrise on September 1st, and this interval increases about an hour each month, so that by the end of October it rises at about 3:30 A.M. It moves during the two months 36° eastward and 14° southward from *Leo* into *Virgo*. On September 9th it passes less than 1° north of the first-magnitude star *Regulus, α Leonis*. *Mars* reaches its aphelion on October 17th. It will then be about one hundred and fifty-five millions of miles distant from the Sun, and about two hundred and twenty-six millions distant from the Earth, a gain of about twenty millions from the greatest distance; and there will be in consequence a gain of nearly twenty per cent in brightness, a perceptible increase, but it will still not be as bright as a first-magnitude star.

Jupiter rises a little after midnight on September 1st, and shortly before 9 P.M. on October 31st. It is in the constellation *Gemini* and moves about 5° eastward during the two months.

Saturn comes to opposition with the Sun and remains above the horizon during the entire night on September 4th. By the end of October it sets at about 3:30 A.M. It is in the extreme eastern part of *Aquarius*, and moves about 3° westward and southward during the two months. The apparent minor axis of the rings as seen in the telescope is about twice as great as it was during June.

Uranus is in the western sky in the evening. On September 1st it sets shortly after midnight, and on October 31st shortly after 8 P.M. Its motion is only about 1° during the two months, at first westward and then eastward, and it remains about 2° north of the third-magnitude star λ *Sagittarii*, the star in the end of the handle of "the milk-dipper."

Neptune rises at about 1 A.M. on September 1st, and at about 9 P.M. on October 31st. It is moving slowly eastward in the constellation *Gemini*.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Note on the Level of Sun-Spots.

A few years ago there was an animated discussion on the level of sun-spots, which did not result in any satisfactory conclusion. While visual and photographic observations, on the whole, seemed to favor the traditional view that spots are depressions in the photosphere, measurements of the intensity of their radiation led to the opinion that they might be elevated regions. For at increasing distances from the center of the Sun the total radiation of spots was observed to decrease less rapidly than that of the adjoining photosphere. It was therefore supposed that the spots must be raised above the denser part of that absorbing stratum which reduces the brightness of the photosphere at the limb.

Recent observations on Mt. Wilson, made for the most part by Mr. Abbot with the bolometer, have shown that the radiation of sun-spots, as compared with that of the photosphere, is relatively much richer in the less refrangible rays. In other words, the sun-spots would show with but little contrast in a monochromatic red image of the Sun, while they would appear very dark in a violet image. This result is confirmed by our photographs of spot spectra, which require a relatively larger exposure to bring out the umbra in the violet than in the red. There is thus no doubt that spots are relatively richer than the photosphere in red rays.

The knowledge of this fact reduces and probably completely removes the difficulty encountered in the discussion mentioned above. As the absorption at the Sun's limb is known to be much more marked for the short waves than for the long ones, it is evident that the light of spots will suffer less from absorption than the light of the photosphere. There is consequently no necessity of assuming, at least on these grounds, that the level of spots is higher than that of the

photosphere. It is hoped that a quantitative study of the question may soon be made. GEORGE E. HALE.

NEW COMPANIONS TO TWO STRUVE STARS.

Examination with the 36-inch telescope has recently shown that the principal component in each of the two well-known double stars, Σ 1729 and Σ 2668, is itself a close unequal pair. My measures of the old and new companions are as follows:—

Σ 1729.

A and B (New).

Date.	Angle.	Dist.	Magnitudes.	
1906.50	120°.8	0″.29	8.9-10.3	3ⁿ

A B and C.

1906.47	274°.8	8″.46	8.8-11.0	1ⁿ

Σ 2668.

A and B (New).

1906.54	111°.5	0″.26	7.0-9.0	2ⁿ

A B and C.

1906.54	286°.3	3″.26	6.8-9.0	2ⁿ

STRUVE'S measure of the latter pair is, 1831.14 293°.6 3″.30. perhaps indicating very slow motion. Σ 1729 has shown no motion whatever in the seventy-five years since its discovery. R. G. AITKEN.

July 21, 1906.

A ROAD TO MT. WILSON.

On the occasion of President WOODWARD's recent visit to the Solar Observatory, it was decided to widen the "New Trail," which ascends from the foot of Eaton Cañon, into a road suitable for the transportation of the heavy castings of the 5-foot reflector mounting. President WOODWARD recommended that Mr. GODFREY SYKES, superintendent of construction at the Desert Botanical Laboratory of the Carnegie Institution, be placed in immediate charge of the work, on account of his skill as an engineer and his experience in the building of trails in Arizona. This was rendered possible through the courtesy of Director MACDOUGAL, of the Botanical Laboratory, who arranged to give Mr. SYKES a leave of absence.

Work has been commenced, and will be pushed forward as rapidly as possible, in the hope that the structural steel for the building which is to contain the 5-foot reflector may be sent up the mountain in May, 1907.

The width of the road, which is determined by the size of the large castings to be transported, will average about eight feet, widening to ten feet or more on the turns. The automobile truck, on which the materials for the building and telescope will be carried, has been ordered from the Couple-Gear Freight-Wheel Company, of Grand Rapids. It has been specially designed for the purpose, as the 10-foot worm-gear and other large and cumbersome parts of the mounting (some of them weighing five tons each) could not be carried on the standard truck. The motive power will be a gasoline engine of about forty horse-power, driving a large direct-current dynamo. The dynamo will supply current to four motors mounted within the four wheels of the truck. This truck, which is capable of turning within a very small circle, has been tested by Professor RITCHEY and found to be remarkably well adapted for our purpose. It can be steered equally well from either end, thus permitting it to be reversed, if necessary, at sharp re-entrant turns.

As soon as completed, the truck will be used in the construction work on the trail. For this purpose it will carry an air-compressor of sufficient capacity to supply several rock-drills. The compressor will be driven by the gasoline engine of the truck, and will greatly reduce the cost of the rockwork.

GEORGE E. HALE.

NOTE ON THE VARIABLE RADIAL VELOCITY AND THE PERIOD OF *SU CYGNI*.

Preliminary measures of ten spectrograms of *SU Cygni*, taken with the one-prism spectrograph during June and July, 1906, show a variation of about forty kilometers per second in its radial velocity, and prove its binary character.

The velocity and light variation seem to have the same period, the phases of the former following those of the latter by about half a day.

Photometric measures of the star on seven nights in June and July of this year indicate that its maxima now precede the

times computed from LUIZET's elements[1] by about 0.4 days. The period is therefore about 3.8455 days.

July 30, 1906. JAMES D. MADDRILL.

APPOINTMENTS TO LICK OBSERVATORY STAFF.

Dr. BURT L. NEWKIRK, Instructor in Mathematics, University of California, has been appointed Assistant in the Lick Observatory on the Carnegie Institution Foundation, with principal duties in the measurement of spectrograms for determining the radial velocities of stars.

Mr. E. A. FATH, recently Assistant in the Observatory of the University of Illinois, has been appointed Fellow in the Lick Observatory.

Mr. G. B. BLAIR, recently Assistant in the Allegheny Observatory, has been appointed Fellow in the Lick Observatory.

MT. HAMILTON, July 31, 1906. W. W. CAMPBELL.

[1] *A. N.*, Vol. 149, 316, 1899.

GENERAL NOTES.

The *Astronomische Nachrichten,* No. 4101, contains a plan for a Durchmusterung of variable stars proposed by Professor SOLON I. BAILEY and presented by Professor E. C. PICKERING. The plan involves the examination of all stars of the sixteenth magnitude or brighter (estimated at fifty millions in number). The instrumental equipment suggested involves only an eight-inch photographic telescope of the doublet type, with the possible addition of a stereocomparator to aid in the comparison of plates. It is contemplated that amateurs and observatories of modest instrumental equipment should take a prominent part in this work, which would occupy the attention of variable-star observers for a generation.

The plan is simply to make several photographs of a particular region of the sky at intervals covering a period of several months, and, by a comparison of the plates, pick out the stars that show evidence of variability.

Particular attention is called to the value of negative results which establish the fact that any portion of the sky is lacking in variable stars.

Stereoscopic Determinations of Proper Motion.—The stereocomparator was ushered into the astronomical world at the meeting of the Astronomische Gesellschaft in Göttingen in the summer of 1902, where it was placed on exhibition and aroused general interest. It is described in No. 94 of these *Publications,* p. 22. One of these instruments forms part of the equipment of the Astrophysical Institute at Heidelberg, and the Director, Professor MAX WOLF, announces in No. 4101 of the *Astronomische Nachrichten* some interesting results obtained with its help. He finds that slight relative differences in the positions of star-images on two photographic plates can be measured with great accuracy. These changes of position may be due to any one of several causes, or to a combination of them. Most important of these causes are proper motion of some of the stars, and differential refraction effects, due to differences in the color of the stars. The ease with which displacements of a few seconds of arc can be detected, as

well as the accuracy with which they can be measured, combine to make this instrument one of remarkable promise. Professor WOLF'S results indicate the possibility of measuring relative displacements with an accuracy of less than a second of arc on plates made with a lens of about thirty-two inches' focal length. Differences in the color (i. e. spectral characteristics) betray themselves by the displacements due to differential refraction, or by a comparison of plates made with lenses of equal focal length, but corrected for different wave-lengths, when the exposure is made at considerable zenith-distance.

The application of the stereoscopic principle promises to play an important role in future astronomical investigation. Its chief and obvious advantage lies in the striking manner in which relative displacements amounting to a hundredth of a millimeter or more are brought out, rendering their detection possible without a laborious process of measurement and reduction. Whether the accuracy of the photographic method will be materially increased by the application of this principle remains to be seen. B. L. N.

The following notes have been taken from recent numbers of *Science*:—

Columbia University is to have a six-inch equatorial, suitable for student work. The glass has been presented by Mrs. WILDE, and completely refined and refigured by Messrs. Alvan Clark's Sons, of Cambridgeport.

At the meeting of the council of the Royal Astronomical Society held on June 1st the following resolution was unanimously agreed to: "That the council learn with deep concern of the danger threatened to the Royal Observatory, Greenwich, from the erection of a large electric-generating station near the observatory, and desire to represent to the Admiralty at the earliest possible opportunity their conviction of the paramount importance of maintaining the integrity and efficiency of Greenwich Observatory which has been adopted as the reference-point for the whole world."

Professor SIMON NEWCOMB has been elected a member of the board of overseers of Harvard College.

The death is announced of M. RAYET, director of the observatory and professor in the University of Bordeaux.

The following extracts have been taken from an account in the London *Times* of the report of the Astronomer Royal to the board of visitors of the Royal Observatory, Greenwich:

"The astrographic equatorial has been chiefly used for making new chart plates, some of those previously passed being unsuitable for photographic reproduction. Eighty-three chart plates were taken during the year, thirty-five of *Jupiter* and surrounding stars, two of *Mars* and surrounding stars. The Astrographic Catalogue is nearing completion, the zones from 64 to 84 north declination having now been printed, leaving only six more degrees to finish it. It will contain about 178,000 stars; seven times as many as the most extensive catalogue of the region hitherto in existence—viz., the Bonn Durchmusterung. The chart will contain nearly four times as many stars as the catalogue; it is being pushed on rapidly, 12,000 prints, reproducing 191 plates, having been taken during the year; 401 plates, about one third of the whole, have now been reproduced. The reproductions are on bromide cards, twice the linear scale of the plates, and are distributed to about fifty institutions, including the leading observatories.

"The 30-inch reflector has been used for the photography of *Jupiter's* new satellites, comets, and minor planets; eighty-six photographs were obtained of satellite VI, which is of the fourteenth magnitude, and nineteen of satellite VII, which is of the sixteenth magnitude. As far as is known these are the only photographs of satellite VII obtained elsewhere than at the Lick Observatory, and they will be of use in improving the determination of its orbit. The orbits of the two satellites are nearly equal in size, the periods of revolution being 251 days and 257 days, implying distances of about seven millions of miles from *Jupiter*. Both orbits are eccentric and inclined about thirty degrees to *Jupiter's* orbit, though their planes of motion are quite different. It was at first thought that they might go round *Jupiter* in a retrograde direction, like *Phœbe, Saturn's* ninth satellite, but this has now been disproved. One of the more interesting comets photographed has been that discovered by KOPFF at Heidelberg last March. It has an immense perihelion distance, three and one third times as great as the Earth's distance from the Sun, and had passed perihelion five months before discovery. The photographs show a much more definite outline than is commonly the case with comets.

"Mr. COWELL has concluded the analysis of all the Greenwich observations of the Moon since 1750, which was in progress at the date of the last report. Values have been deduced for the coefficients of all the solar perturbations and compared with the theoretical values found by HANSEN and BROWN, the agreement in most cases being very satisfactory. Mr. COWELL finds evidence for the existence of three empirical terms, two being small ones with periods of about half a century, the third a large term with a period of over three centuries. The necessity for a term of this character had been already

pointed out by Professor NEWCOMB, but Mr. COWELL has altered the period and the coefficient. The search for a physical explanation of this large term has so far been in vain, and it is at present one of the outstanding mysteries of gravitational astronomy. The presence of this term makes it impossible to deduce the secular acceleration of the Moon from modern observation, and Mr. COWELL has re-examined the ancient eclipses of the Sun and Moon with a view to its determination. He has selected six solar eclipses, of which the records appear fairly definite and satisfactory, the earliest being one in B. C. 1063, recently discovered by Mr. KING, of the British Museum, in a Babylonian inscription. On the hypothesis that the Moon has an acceleration of eleven seconds per century, and the Sun one of four seconds, it was found possible to represent satisfactorily all the above solar eclipses, besides several of the lunar eclipses recorded by PTOLEMY. There are thus considerable grounds for accepting the above accelerations. The acceleration of the Sun was at first rather perplexing, as it appeared contrary to gravitational theory, unless the supposition was made that the Earth was moving in a resisting medium. But a more probable explanation has recently been arrived at—namely, that the acceleration is only apparent and is due to a retardation of the Earth's rotation by tidal friction, and a consequent lengthening of the day. Now, in all his computations the day, not the year, has been taken as the unit of time, and consequently a lengthening of that unit would produce an apparent acceleration in the motion of all the heavenly bodies. Of the eleven seconds found for the lunar acceleration, six seconds are known to be due to the diminution in the eccentricity of the Earth's orbit, leaving five seconds to be accounted for by tidal friction. At first sight this would appear to imply a solar acceleration only one twelfth as great, or practically insensible. But, by the principle of the conservation of angular momentum, a retardation of the Earth's rotation involves an increase in the Moon's distance, and a consequent lengthening of her period. This effect would mask the greater part of the apparent acceleration due to the lengthening day, so that the observed amount for the Moon is quite consistent with a solar acceleration of several seconds. This principle had been enunciated by Sir GEORGE DARWIN twenty-five years ago in his researches on the birth of satellites by tidal evolution; but the necessity of applying such a correction to the actual observations of the Moon had been strangely overlooked till the present time. It must be admitted that the descriptions of the ancient eclipses are not quite so definite as could be desired, but the agreement of six of them undoubtedly gives considerable weight to the result, according to which the day is lengthening by one two-hundredth of a second in a century.

"The solar activity in 1905 was pronounced, being double that for 1904; as 1906 has so far shown a falling off, the sun-spot *maximum* appears to be over. Arrangements have been made for taking enlarged photographs of interesting spot groups on a scale of thirty inches to the Sun's diameter, with the 26-inch photographic refractor. The

sun-spot photographs taken between 1874 and 1885, re-enforced by photographs taken at Harvard and Melbourne, have now been measured, and the results printed, thus making a continuous series from 1874 to the present time. In spite of the great sun-spot activity in 1905, there were no days of great magnetic disturbance, and only twelve of lesser disturbance.

"The Astronomer Royal alludes in his report to the anxiety caused by the opening of the new generating station at Greenwich, which is half a mile due north of the observatory. It is feared that smoke and heated air may affect the observations of low north stars, and there is evidence that the vibration caused by the engines produces sensible tremors in the mercury trough used for reflection observations of the nadir and of stars.

"The staff has suffered the loss of Mr. F. W. DYSON, who was appointed Astronomer Royal for Scotland on the death of Dr. COPELAND. Mr. A. S. EDDINGTON, scholar of Trinity College, Cambridge, and Senior Wrangler in 1904, has been appointed to fill his place."

REVIEW.

AN INTRODUCTION TO ASTRONOMY. By FOREST RAY MOULTON, Ph. D., Assistant Professor of Astronomy in the University of Chicago. Author of "An Introduction to Celestial Mechanics." New York: The Macmillan Company, 1906. xviii + 557 pages.

In this work Professor MOULTON adds a very interesting and valuable contribution to the literature of descriptive astronomy. To quote from the preface, "An attempt has been made in this volume to give an introductory account of the present state of the science of astronomy. The aim has been to present the subject so that it shall be easily comprehended by the student without mathematical or extensive scientific training, and so that he may obtain from it not only some knowledge of scientific achievements, but also something of the spirit which inspires scientific work." In the opinion of the writer, Professor MOULTON has been generally successful in this attempt, but has failed in some few particulars. The subject-matter of the first chapters is simply and elegantly presented, but when he gets to the subjects of perturbations and evolution of the universe, in which the author is perfectly at home, he becomes too technical for the average student and handles such formidable terms as "moment of momentum" as though they were quite commonplace expressions. It takes one well acquainted with these subjects to read those chapters understandingly. But to such a one the subjects are presented in a most enjoyable manner. In view of this, it seems difficult to determine for what class of readers the work is intended.

On the whole, the author has succeeded in giving a very satisfactory "account of the present state of the science of astronomy." The book is thoroughly up to date, and very valuable for reference. A copy should be included in every student's library. It is exceedingly well written and well illustrated, and suggests lists of the best works for reference. Sketches of the historical development of various problems are well placed throughout the book. Interest is added here and there by philosophical and psychological discussions on

subjects such as "Equal intervals of time," "Science," "Induction and deduction," etc.

In presenting various theories the author criticises them most fairly and presents all sides with skill. His explanations of modern developments, such as HALE's recent solar investigations, etc., are very good. In many places he gives very clear expositions of different conditions associated with critical stages of periodic changes in different phenomena,—*e. g.* seasons, various inclinations of Moon's orbit to the equator, etc. Sets of interesting and valuable questions are interspersed throughout.

In the opinion of the writer, there are a few minor adverse criticisms, which will be noted in passing. The author was not compiling a dictionary, and it should not be necessary in a work of this kind to explain the meaning of words such as "luminiferous," "sidereal," "chromatic," etc. I, for one, object to the author's persistent use of the word "planetoid." Scientific literature is too permeated with the word "asteroid" to make the change just for etymological consistency. The word "mare," for instance, will probably always be used in lunar topography; so why change from "asteroid" to "planetoid"?

In the printing of numerical parts the usual form such as $8''.7$ seems better than that of $8.7''$ used in the text.

While I have not verified all of the numerical data given, such as those on page 294, I have looked into the more important of them and find them generally correct. In making detailed criticisms by chapters attention will be called to the errors noted.

Chapter I gives the "Preliminary Outline."

Chapter II—"Reference Points and Lines." In several places in defining reference points and lines the sequence is not good. For instance, the vernal equinox is first mentioned on page 30 and is defined on page 32.

Chapter III—"Constellations." This chapter is most pleasing and useful. The introduction of the star-maps is a good feature, and the description of the constellations is well designed to create an interest in observation.

Errata: Page 51, below *Rigel* read *β Orionis* for *α Orionis;*

below *Betelguese* read *α Orionis* for *β Orionis;* line 7 from bottom insert minus sign before the declination.

Chapter IV—"Telescopes." In this chapter the optical features of telescopes are very clearly presented.

In the opinion of the writer the method of finding magnifying power (pp. 85-86) is not described completely; mention should have been made of finding the focus of the image of the objective.

Figure 41 (p. 109) presents a very poor chronographic record. The rate of the chronograph was bad and the signals for transits are much too long.

Erratum: Page 85, section 70.—The first sentence defines the *reciprocal* of magnifying power instead of magnifying power itself, as stated.

Chapter V on "The Earth" is extremely good.

Chapter VI—"The Motions of the Earth." The subject-matter of this chapter is well presented. The writer thinks that in discussing variations of latitude his list of stations should have included those in Siberia, Italy, and Cincinnati.

Chapter VII—"The Law of Gravitation." This chapter is excellent. Mention might well have been made of the so-called Invariable Plane.

Chapter VIII—"Time." In this chapter the all-important idea that time is hour-angle is not brought out.

The "mean sun" is not once mentioned. The author may have had some reason for this which is not apparent to me.

Erratum: Page 241.—The Julian calendar is now (since 1900) thirteen days behind the Gregorian, instead of twelve days, as stated in the text.

Chapter IX—"The Moon."

Chapter X—"Eclipses." This subject is presented with great clearness.

Erratum: Page 278, fig. 109.—The point called B in the text has been omitted from the figure.

Chapter XI—"The Solar System." In the opinion of the writer the various methods of determining solar parallax are not fully enough explained.

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PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1906.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter.	Nov.	9,	$1^h\,45^m$	A.M.	Last Quarter..	Dec.	8,	$5^h\,45^m$ P.M.
New Moon...	"	16,	12 36	A.M.	New Moon....	"	15,	10 54 A.M.
First Quarter.	"	22,	4 39	P.M.	First Quarter.	"	22,	7 4 A.M.
Full Moon...	"	30,	3 7	P.M.	Full Moon....	"	30,	10 44 A.M.

The winter solstice, the time when the Sun begins its northward motion and winter begins, comes on December 22d, about 10 A.M., Pacific time.

Mercury is an evening star on November 1st, setting not quite an hour after sunset. This interval increases slightly, and is a little over an hour at the middle of the month. The planet reaches greatest east elongation ($23^\circ\ 0'$) on November 9th, and after a few days begins to approach the Sun quite rapidly. It passes inferior conjunction with the Sun on the evening of November 29th and becomes a morning star. After that it moves rapidly out toward greatest west elongation, and reaches this situation on December 18th. It then rises more than an hour and three quarters before sunrise, and the interval diminishes only slightly during the rest of the month, being not quite an hour and one half on December 31st. It will therefore be in good position for observation on any clear morning after about December 10th.

Venus is still an evening star on November 1st, setting not quite an hour and one half after sunset. By the middle of the month it is less than one hour behind the Sun but may still be seen in the evening twilight. It reaches inferior con-

junction on November 29th and becomes a morning star. After that it moves rapidly away from the Sun on a path which carries it considerably to the north of the Sun, so that by December 16th it rises two hours before and on December 31st three hours before sunrise.

The relative motions of *Mercury* and *Venus* during November and December are interesting. On November 1st both are evening stars, *Venus* being about 12° farther from the Sun than *Mercury*. *Mercury* keeps on increasing its distance from the Sun until November 9th, while *Venus* continually approaches it. On the evening of November 14th *Venus* overtakes and passes *Mercury*, the nearest approach being about 2°, *Venus* south. Both are still far enough away from the Sun to be seen in the evening twilight, if the weather is good. *Venus* is now ahead in the race toward the Sun, but *Mercury* soon begins to gain and reaches conjunction with the Sun only an hour after *Venus*, on November 29th. It overtakes and passes *Venus* fifteen hours later, but both planets are of course too near the Sun to be seen. They are now morning stars, both receding from the Sun, but *Mercury's* burst of speed soon gives out, and *Venus* overtakes and passes it on the morning of December 15th, *Venus* being a little less than 1° south. Both of the planets are now far enough away from the Sun to be seen in the morning twilight.

Mars is now a morning star, gradually increasing its distance from the Sun. On November 1st it rises at about 3:30, and on December 31st at about 2:30. During this period it moves about 35° eastward and 14° southward through *Virgo*. On November 14th it passes a little more than 1° south of the third-magnitude star γ *Virginis*, and on December 3d about 3° north of the first-magnitude star *Spica*, α *Virginis*. By the end of December its distance from the Earth will have diminished to about seventy per cent of the maximum which it had in July, and its brightness will consequently have just about doubled. It will be nearly as bright as the first-magnitude star *Spica*, which is near it through December.

Jupiter is getting into good position for observation in the eastern sky in the evening. On November 1st it rises at a little before 9 P.M., and at a little before sunset on December 31st. It comes to opposition with the Sun on the morning of December 28th. It is in the western part of the constellation *Gemini*,

and its motion is retrograde, about 6° westward. It is south and west of the principal stars of *Gemini, Castor* and *Pollux,* and in the general direction of *Aldebaran,* the brightest star in *Taurus,* but rather nearer the former pair.

Saturn is also in good position for evening observation, but is in the southwestern sky. It remains above the horizon until about 1:30 A.M. on November 1st, and on December 31st does not set until nearly 10 P.M. It is in the eastern part of *Aquarius* and moves slowly westward until November 12th. After that it moves eastward and northward about 2°. The apparent breadth of the rings begins again to diminish, but does not become as small as it was in June.

Uranus is also in the western sky in the evening, but is considerably nearer the Sun than is *Saturn.* It sets shortly after 8 P.M. on November 1st, and the apparent distance from the Sun diminshes until the planet comes to conjunction on December 30th. It is still in the constellation *Sagittarius,* and moves about 3° eastward during the two months. The nearest bright star is still λ *Sagittarii.* After December 1st the planet will be too near the Sun for naked-eye view.

Neptune rises about 9 P.M. on November 1st, and before 5 P.M. December 31st. It is still in *Gemini.*

NOTES FROM PACIFIC COAST OBSERVATORIES.

On the Cause of the Characteristic Phenomena of Sun-Spot Spectra.

In considering the characteristic features of the spectra of sun-spots, three points especially attract attention:—

1. The fact that certain lines in the spectrum of a given element are strengthened, while others are weakened; the remainder of the lines being unaffected.

2. The inclusion of all the strengthened lines within the visible spectrum, none of them occurring in the ultra-violet, and their predominance in the red, yellow, and green.

3. The relatively great intensity of the continuous background of the spot spectrum in the less refrangible region.

From our general knowledge of spectra corresponding to various temperatures we are aware—

1. That in passing from a high temperature to a lower temperature, certain lines are strengthened, some are unaffected, and others are diminished in intensity.

2. That such a reduction of temperature is accompanied by an increase in the relative intensity of the less refrangible lines, and a shift of the maximum of a continuous spectrum toward the red.

The general correspondence of these two groups of facts led us to seek for an explanation of the spectra of sun-spots, on the hypothesis that the metallic vapors within the spots have a temperature lower than that of the photosphere.

The investigation was begun with the aid of a synchronous rotating arc, of Crew's design, which permits the spectrum of the alternating arc to be photographed at any desired phase. Subsequently an ordinary arc was employed, with currents of thirty amperes and two amperes respectively. The lines in the spectra of iron, titanium, vanadium, chromium, manganese, and other metals characteristic of sun-spots, were found

to show changes of intensity similar to those observed in spots, when passing from high phase to low phase, or from large currents to small currents. All the evidence favored the view that the effect of such variations in the arcs is to lower the temperature. This conclusion was subsequently confirmed with the aid of the flame of the arc and with an electric furnace. In the latter the metals are volatilized within a carbon tube, the outer wall of which is heated by a powerful electric arc. At the low temperatures obtained within the tube spectra closely resembling the spectra of the corresponding elements in sun-spots have been photographed.

The results are given in full in *Contributions from the Solar Observatory*, No. 11. They may be summarized as follows:—

Considering first the lines strengthened in sun-spots and those strengthened in the two-ampere arc or in the flame of the arc, we have the following table:—

Element.	No. of Lines Strengthened in Spots.	No. of Lines Strengthened in Weak Arc.	Unchanged Weak Arc.
Ti.....	88	83	5
Cr.....	46	42	4
Fe.....	19	18	1
V.....	56	52	4
Mn.....	11	9	2
	220	204	16

A comparison of the lines weakened in spots with the same lines in the spark and two-ampere arc or flame gives the following result:—

Element.	No. Lines Weakened in Spot.	No. These Enhanced in Spark.	No. Not Changed in Spark.	No. Diminished in Weak Arc.	No. Not Seen in Weak Arc.	No. Not Changed in Weak Arc.
Ti.....	8	8	0	8	0	0
Cr.....	10	10	0	6	4	0
Fe.....	13	10	3	9	3	1
Mn.....	1	1	0	1	0	0
	32	29	3	24	7	1

It is thus evident that more than 90 per cent of the lines that are strengthened in our photographs of sun-spot spectra, and included in this investigation, are strengthened in passing from a thirty-ampere arc to a two-ampere arc or to the flame.

A similar proportion of the lines that are weakened in sun-spots are weakened under the same conditions. We have also found that the lines whose intensities are unchanged in sun-spots are, speaking generally, unchanged under the conditions named. As a further fact, of great importance in its bearing upon the temperature of the vapors in sun-spots and the classification of stellar spectra, we also find that over 90 per cent of all the "enhanced" (spark) lines included in our tables are weakened or absent in the two-ampere arc and in the flame.

We conclude that the temperature of the vapors in sun-spots is probably below that of the same vapors in the ordinary reversing layer. As we have recently shown that the spectra of third-type stars closely resemble spot spectra, and as this resemblance is greatly enhanced through our recent discovery of the titanium oxide fluting, which begins at λ 5597.9, in our photographs of spot spectra, further investigations along these lines seem likely to prove fruitful.

GEORGE E. HALE,
WALTER S. ADAMS, and
HENRY G. GALE.

FINLAY'S PERIODIC COMET (1906 *d*).

This comet was discovered by FINLAY in 1886. It returned to the Sun in 1893 and 1900, and was rediscovered on its third return by KOPFF, of Heidelberg, on the morning of July 17, 1906. A search ephemeris had been computed by M. FAYET, of Paris, and published in the same number of *Astronomische Nachrichten* with the printed announcement of discovery.

The comet was looked for at the Lick Observatory on July 20th, when it was easily seen in the 3-inch finder of the 12-inch equatorial. Since then it has been observed a number of times, the last at present writing (September 20th) being on September 16th. From the time of rediscovery it grew continuously brighter until about the middle of August; since then it has grown fainter, but at no time was it visible to the naked eye. On July 20th there was a faint nucleus of about the twelfth magnitude, surrounded by a diffuse nebulous mass. This condensation was barely of magnitude 13.5 on September 16th. No tail had been found at the time of the last observation.

E. A. FATH.

September 20, 1906.

Reobservation of *Phœbe*, the Ninth Satellite of *Saturn*.

The first photograph of *Phœbe* at the present opposition was secured with the Crossley reflector on July 18th.

The position of the satellite at $14^h\ 41^m\ 23^s$, P. S. T., was

α	23^h	5^m	$12^s.85$
δ	$-7°$	$59'$	$36''.0$

or, with respect to *Saturn*,—

1^m	$10^s.35$	west
$6'$	$53''.5$	south

This position is within 1^s in α and $0'.1$ in δ of the place predicted for it by Dr. Ross.

Other observations were secured on July 19th, 20th, August 14th, 16th, and 17th. *Phœbe* is now too close to *Saturn* for observation with the Crossley.

C. D. Perrine.

September 12, 1906.

Reobservation of *Jupiter's* Sixth Satellite.

The first observation of the Sixth satellite, at the present opposition, was secured on August 26th. Its position at $15^h\ 10^m\ 30^s$, P. S. T., was

R. A.	6^h	21^m	$24^s.99$
Decl.	$+22°$	$38'$	$32''.0$

Its position with reference to *Jupiter* was—

Position-angle	$210°$	$14'$
Distance		$29'.0$

September 14, 1906.

C. D. Perrine.

Note on Comet *e* 1906 (Kopff).

The fifth comet of this year was discovered near opposition August 22d by Kopff at Heidelberg. Three observations by Mr. Fath, on August 24th, 25th, and 26th, were kindly telegraphed to the Student's Observatory by Director Campbell. These revealed a very slow motion. From them a preliminary orbit was deduced, which has been printed in *Lick Observatory Bulletin*, No. 99.

A second orbit based upon observations made by Mr. Fath, August 24th, September 5th, and September 15th, has just

been completed. As was expected, large variations from the first elements were found. These three observations cannot be represented by a parabola. They lie, however, on an ellipse whose semi-major axis is 3.54 astronomical units. The period is about six and two-thirds years. Its nearest approach to the Sun was May 2d, at which time it was 158,000,000 miles from it.

The plane of this second orbit is inclined 8° 44′ to the plane of the ecliptic. The longitude of perihelion is 283°. The comet is receding from both the Earth and the Sun, so that it is becoming fainter. It can no longer be seen with a telescope of moderate size, and will soon be too faint for any but the largest telescopes.

An ephemeris giving the positions of the comet up to November 2d is printed with these second elements in *Lick Observatory Bulletin*, No. 100. The comet is at present traveling southwest through the southern part of *Pegasus*. On October 10th it will be in Right Ascension $22^h\ 26^m$, and 5° 46′ north of the equator.

RUSSELL TRACY CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT.
September 22, 1906.

NOTE ON Σ 2028 (Rej.).

In the *Mensuræ Micrometricæ* fourteen stars, originally suspected of being double but finally rejected as single, are omitted by STRUVE. Among these is Σ 2028, which, in his 1827 catalogue, was marked "oblonga?" but evidently was not seen in subsequent years. I examined this star (B. D. + 39° 2963) with the 12-inch telescope on the night of September 4, 1906, and at once saw that it was really double. A measure with the 36-inch on September 7th gives 146°.8, 0″.49, magnitudes 8.0 and 8.5. It is worth noting that this is the only star finally rejected by STRUVE as single that has since been found to be double.

R. G. AITKEN.

September 17, 1906.

A 100-INCH MIRROR FOR THE SOLAR OBSERVATORY.

I am permitted to announce that Mr. JOHN D. HOOKER, of Los Angeles, has presented to the Carnegie Institution of Washington the sum of $45,000, to be used to purchase for the Solar Observatory a glass disk 100 inches in diameter

and thirteen inches thick, and to meet other expenses incident to the construction of a 100-inch mirror for a reflecting telescope of fifty feet focal length. The optical work will be done by Professor G. W. RITCHEY and the assistant opticians employed under his direction by the Solar Observatory.

In *Contributions from the Solar Observatory*, No. 13, I have outlined the difficulties that must be overcome in the construction and use of a 100-inch mirror. These include—

(1) The manufacture of a suitable glass disk. In view of their long experience and full understanding of the requirements, it seems probable that the St. Gobain Company will be able to make a satisfactory disk, although the amount of glass to be cast in a single piece will weigh over four and one half tons.

(2) The production of a perfect paraboloidal figure. After his successful work with the 60-inch reflector, Mr. RITCHEY will undoubtedly be able to accomplish this difficult task.

(3) The design and construction of a mounting capable of carrying the mirror with the necessary accuracy. There seems no reason to doubt that the experience gained from the use of the 60-inch reflector will render it possible to design a satisfactory mounting, which the Union Iron Works Company will be able to construct in such a way as to meet all requirements.

(4) Serious changes of focal length, due to variations in the temperature of the mirrors. The fact that the night temperature on Mt. Wilson is nearly constant after 9 P.M., during the best observing season, and the possibility of maintaining the mirrors during the day at the average night temperature by means of a refrigerating plant, seem to indicate that no insuperable difficulties will arise from this cause.

(5) Imperfect seeing. Our tests of the definition at night on Mt. Wilson, made with the Snow telescope and smaller instruments, lead us to believe that the occasions on which the full aperture of the mirror can be used for the most exacting work will not be very infrequent. The average conditions will undoubtedly permit the 100-inch reflector to be used advantageously in the various classes of work in which large light-gathering power, rather than the most perfect definition, is essential.

The funds for the mounting, dome, and building required for the 100-inch mirror have not yet been obtained. I have

some reason to believe, however, that a donor can be found. As these mechanical parts can be constructed in a single year, while the completion of the mirror will require four years, there is no need of haste in this regard.

GEORGE E. HALE.

REOBSERVATION OF THE SEVENTH SATELLITE OF *JUPITER*.

The first observation of the seventh satellite of *Jupiter* at the present opposition was secured with the Crossley reflector on September 17th. The image of the satellite (with one hour's exposure) is extremely faint. The identity of the object was only made certain from plates secured on September 25th and 26th with longer exposures.

The position of the satellite with respect to its primary on September 25th, at $23^h\ 54^m\ 30^s$, P. S. T., was

Position-angle	119° 4′
Distance	42″.96

A comparison of this place with Ross's ephemeris, published in *A. N.* 4101, gives the following residuals—in the sense observed *minus* ephemeris:—

Position-angle	−1°.1
Distance	+0″.2

This must be considered a very satisfactory agreement.

MT. HAMILTON, CALIFORNIA,
September 28, 1906.

C. D. PERRINE.

ERRATUM.

In No. 109, these *Publications*, p. 262, line 9, for 13.2 read 132.

GENERAL NOTES.

Stellar Parallax Work at the Yale Observatory.—The heliometer at the Astronomical Observatory of Yale University—the only instrument of its kind in this country—has been devoted principally to observations for determining the parallaxes of stars. Dr. ELKIN's work on the Parallaxes of the Stars of the First Magnitude is recognized as one of the most valuable contributions to our knowledge in this difficult field.

It is generally known that another important piece of work, having for its object a more extended survey of fainter stars with large proper motion, has been in progress with this heliometer for some years, and the results have been looked for with great interest. They are now made public in Part I of Volume II of the Transactions of the Astronomical Observatory of Yale University, which is entitled "Parallax Investigations of One Hundred and Sixty-three Stars Mainly of Large Proper Motion." The great bulk of the work has been executed by Dr. CHASE, Assistant Astronomer, who has devoted to it the larger part of the past thirteen years; but Mr. MASON F. SMITH, Assistant, and Dr. ELKIN, the Director, have also taken part in it, the relative shares of the three observers being about as ten to two to one, respectively.

The Introduction describes the selection of the programme of work and the method of observation and reduction. It was at first planned to make only a few observations—three or four—at two successive epochs of maximum parallactic effect, it being assumed that these would be sufficient to show with certainty parallaxes as large as 0″.20 and to indicate values as large as 0″.10. The stars with large parallaxes were then to be observed more exhaustively. Later it seemed desirable to extend the observations over two more epochs taken in reverse order, to eliminate more completely the effects of proper motion and any systematic errors of observation. More stars were also added to the observing-list, including *Arcturus* (results not yet published), several red stars, for the determination of systematic error depending on star-color, and a number of stars selected by Dr. DE BALL, of Vienna, as the

material for a co-operative plan for a stellar parallax campaign based on stellar magnitude.

The results in the present investigation are made to depend solely on measures of distances, two comparison-stars being used, in general, for each star investigated. Every precaution was taken to avoid systematic errors of all kinds, and tests of various kinds were made to check the accuracy of the results.

The main part of the volume gives the details of the measures for each star, the equations of conditions, the normals and their solution, and finally the resulting relative parallax with its probable error. This is followed by a discussion of the observations on the red stars and a general discussion of the results of the parallax work. It is shown that there is a discernible effect on the distance-measures, due to the color of the star, "the mean light of the red star being apparently refracted less than that of the comparison-stars," but the effect is so small—probably not greater than 0″.03 for a highly colored star—that "any vitiation in the parallax results, due to this cause, is presumably well within their probable error."

The table of collected results shows that only two stars were found to have a parallax as great as 0″.20,—viz., 5 *Serpentis,* 5.1 magnitude, and *Lalande* 46650, 8.7 magnitude, —and that only thirty-eight show a parallax equal to 0″.10. In their general conclusions, the authors arrange their results in five tables, in order respectively of Proper Motion, Stellar Magnitude, Size of Parallax, Right Ascension, and Stellar Spectra. In the first, second, and fifth of these tables, Dr. ELKIN'S results for the Ten First-Magnitude Stars in the northern hemisphere are also included.

These tables are of great interest, and bring out clearly some important points. That there should appear, in Table I, a "distinct interdependence of parallax and proper motion" was to be expected. It is noted that the stars with proper motions exceeding 1″ give "uniformly positive and generally appreciable values" for the parallax.

The dependence of parallax upon magnitude is not so clearly brought out in Table II, but a small relation is indicated. More data are needed for the determination of this relation.

Table III emphasizes the connection between proper motion and parallax. Table IV indicates an interesting relation between the parallax and the Right Ascension of the stars,

though the proper motions here also show the same sequence. When the mean values are combined into quadrant groups we have:—

Right Ascension.	Proper Motion.	Parallax.	Number of Stars.	Average Magnitude.
0^h to 6^h	0″.73	0.065	42	6.3
6 to 12	0 .62	0.033	40	6.2
12 to 18	0 .83	0.064	40	6.4
18 to 24	0 .55	0.035	51	5.8

The possibility that a temperature effect might account for this sequence is considered by the authors, but they feel "measurably confident that the relation shown by Table IV is one of actual reality."

Finally, the fifth table fails to show much evidence for the law deduced by KAPTEYN of larger parallaxes for stars with Type II spectra than for stars of Type I; but classes F and H of Type II present marked divergences, the average values for the two being + 0″.079 and + 0″.023, respectively, with sensibly equal average proper motions.

The present writer was pleased to find that four binary stars having reasonably well-determined orbits were included in the list of stars with fairly well-determined parallax.

It may be of interest to give the masses and dimensions of those systems which result from combining these values of the parallax with the orbital elements given in *Lick Observatory Bulletin*, No. 84.

Assuming as units the year, the Earth's distance from the Sun, and the combined mass of the Earth and Sun, we have the formula: $\frac{a}{\pi} = P^{\frac{2}{3}} (m + m')^{\frac{1}{3}}$, when a denotes the semi-major axis of the binary orbit, P the revolution period, $(m + m')$ the combined mass of the two components, and π the parallax.

For the four stars in question we find:—

Star.	a''	P	π	$(m + m')$	a {astron. units.
ζ Herculis	1″.35	$34^y.8$	0″.17	0.42	8
ξ Ursæ Majoris	2 .51	60 .0	0 .17	0.89	15
μ Herculis[1] BC	1 .37	45 .4	0 .12	0.72	11
85 *Pegasi*	0 .78	25 .7	0 .10	0.72	8

[1] The parallax is given for the bright star, *Mu Herculis*, but the micrometer measures show that the faint pair, BC, is physically connected with *Mu*, and it is hence assumed that its components have the same parallax.

So far as these figures go they indicate that the masses of binary systems are of the same order as that of the solar system. The dimensions of these four systems are comparable with those of the orbits of *Saturn* and *Uranus*.

It must be said that comparatively small changes in the values of the parallax and orbit elements result in large changes in the values of the mass and dimensions. Thus Miss CLERKE, using 0″.054 for the parallax of 85 *Pegasi* and SEE's elements ($a = 0''.89$, $P = 24^y.0$) finds $(m + m')$ equal to 11.

R. G. AITKEN.

Planetary Inversion.—The *Monthly Notices* of the Royal Astronomical Society for April, 1906, contain a very interesting and quite elaborate article on "Planetary Inversion," by F. J. M. STRATTON, of Gonville and Caius College, Cambridge. The work is an extension to the other planets of the solar system of Sir GEORGE DARWIN'S theory of tidal friction put forth a number of years ago to explain the evolution of the Earth-Moon system. The primary object of the investigation seems to have been to explain the apparently anomalous condition presented in the retrograde motion of *Phœbe*, the ninth satellite of *Saturn*, discovered some years ago by Professor W. H. PICKERING. The article is far too technical for the general reader to follow, but the author gives an excellent summary of three pages in non-technical language at the conclusion. The author has also written a brief extract, printed in the *Astrophysical Journal* for July, which is reproduced below with the omission of one paragraph.

"In view of the discussion between Professor MOULTON and Professor W. H. PICKERING in the number of the *Astrophysical Journal* for December last, perhaps a brief abstract of the results obtained by applying Sir GEORGE DARWIN'S theory of tidal friction to the question of planetary inversion may be of interest. It seems certain to be the case that if a planet unattended by any satellites has an initial retrograde rotation, its axis of rotation will, under the influence of tidal friction, tilt over until the planet reaches a position of stable equilibrium in which its rotation will be direct. The stable value for the obliquity will be somewhere between 0° and 90°, its exact value depending on the planet's viscosity, rate of rotation around its axis, and of revolution in its orbit.

"If satellites are introduced, the question becomes more complicated, and the stable value of the obliquity will vary with the different conditions as to the number of satellites, their masses, and mean distances. There will be three possible equilibrium values for the obliquity accord-

ing to different circumstances—values very near 0°, 90°, and 180°, respectively. *Jupiter* is certainly approaching the first of these values; assuming for it initial retrograde rotation, its satellite system must have been evolved after its obliquity had under the influence of tidal friction alone decreased to some value less than 90°. *Saturn,* on the other hand, evolved *Phœbe,* and possibly *Iapetus* and *Hyperion,* while its obliquity was still greater than 90°. As its obliquity approached this value, *Phœbe's* orbit moved down to the ecliptic (thus remaining retrograde), while *Iapetus* and *Hyperion* followed *Saturn's* equator over. Later on, the inner satellites were evolved, and under their influence and that of the ring *Saturn* is moving into a stable position of small obliquity. In the cases of *Uranus* and *Neptune,* lack of sufficient data makes it impossible to say with any accuracy what is happening, but it seems most likely that *Neptune* is being driven by its own satellite into a stable position with an obliquity of 180°. The obliquity of *Uranus,* too, is possibly being increased at present, but in this case the result is very doubtful.

"It remains to add that the theory is beset with many difficulties, such as the great extent of time involved and the double factor introduced by the heterogeneity of the planets. It does not, so far as I can see at present, explain the high obliquities of *Jupiter's* recently discovered satellites; but it is an hypothesis which does offer an explanation of the retrograde motion of *Phœbe* in its orbit, and of the retrograde rotations of *Uranus* and *Neptune.*"

The Committee on Bibliography and Astronomical Studies at the Royal Belgian Observatory has undertaken the task of preparing and publishing a list of the observatories and astronomers of the world. It is the intention to include in this list all those who are actively engaged in work for the advancement of astronomical knowledge, and all such who are not connected with any observatory to which inquiries have been addressed are requested to send to M. le Professeur Dr. P. STROOBANT, at the Royal Observatory of Belgium at Uccle, for an inquiry blank.

The following notes have been taken from recent numbers of *Science:*—

Professor HERMANN CARL VOGEL, director of the Astrophysical Observatory at Potsdam, has been elected a correspondent of the Paris Academy of Sciences, in succession to the late Dr. S. P. LANGLEY.

Professor JULIUS FRANZ, director of the Breslau Observatory, has been elected an associate of the Royal Astronomical Society.

Mrs. W. P. FLEMING, curator of astronomical photographs in the Harvard College Observatory, has been elected an honorary fellow of the Royal Astronomical Society. Mrs. FLEMING has also been appointed honorary fellow in the department of astronomy in Wellesley College, in recognition of her distinguished work in astronomy and in gratitude for her helpful co-operation in the establishment of astronomical work in Wellesley College.

Professor EDMUND WEISS, professor of astronomy in the University of Vienna, has been elected a corresponding member of the Paris Academy of Sciences in the room of the late O. STRUVE.

The astronomical fraternity mourns the loss of M. GEORGES RAYET, for twenty-five years director of the Bordeaux Observatory, whose death occurred on the 14th of June. The *Astronomische Nachrichten,* No. 4111, contains a brief account of his career, and the *Bulletin Astronomique* for August contains an account of exercises held in recognition of his eminent services to astronomical science.

Doctor's Degrees.—In *Science* for August 17th there is an article entitled "Doctorates Conferred by American Universities." During the last nine years 2,387 doctorates have been conferred, and of these 1,131 were taken in the sciences. Thirty-one degrees have been granted in astronomy, which stands ninth among the twenty-two sciences enumerated. Four doctorates in astronomy were conferred during the last academic year, as follows: By the University of Chicago, on DELONZA TATE WILSON, "Work on Minor Planets"; by the University of Pennsylvania, on SAMUEL GOODWIN BARTON, "Secular Perturbations Arising from the Action of *Saturn* on *Mars:* an Application of the Method of LOUIS ARNDT"; and on EDITH DABELE KAST, "The Mean Right Ascensions and Proper Motions of One Hundred and Thirty Stars"; by the University of California, on SEBASTIAN ALBRECHT, (I) "A Spectrographic Study of the Fourth Class Variable Stars Y *Ophiuchi* and T *Vulpeculæ*," (II) "On the Distortion of Photographic Films on Glass."

REVIEW.

MEASURES OF THE DOUBLE STARS CONTAINED IN THE MENSURÆ MICROMETRICÆ OF F. G. W. STRUVE COLLECTED AND DISCUSSED . . . By THOMAS LEWIS. London: Royal Astronomical Society, Burlington House. 1906.

The 2,640 double stars contained in STRUVE'S great work, familiarly known as the *Mensuræ Micrometricæ*, have, since its publication in 1837, furnished a large proportion of the material for the measures and studies of all double-star observers. Fully one hundred different professional and amateur astronomers have devoted some portion of their time to these stars, and the papers relating to them are widely scattered through the astronomical and other scientific journals and the transactions of scientific societies. To collect these papers, present their contents within the limits of a single volume in such form as to show the nature of the relation existing between the stars of these 2,640 systems, and discuss in more detail the more interesting ones, as well as some general problems relating to double stars, is the task Mr. LEWIS set for himself in preparing the work now under review. Both by his long experience as an observer and computer of orbits of double stars and by his thorough acquaintance with the literature of the subject Mr. LEWIS is well qualified for such an undertaking, and the result of his labors is a volume that will prove of great interest and value to all workers in the field of double-star astronomy.

It is natural to compare his work with the two similar volumes that have appeared in recent years—BURNHAM'S General Catalogue of his own discoveries, and HUSSEY'S volume on the Otto Struve Stars. When this is done two main points of difference are at once apparent. Mr. LEWIS has not attempted to remeasure all the stars he discusses, nor even to secure measures of all of them. In many cases DEMBOWSKI'S measures, made thirty or forty years ago, are the last ones given. This, however, is no detriment to the work, for in

practically all cases the data given show the nature of the stellar system as clearly as is possible at the present time. Only measures extended over a longer series of years can add information of real value.

The second important difference is the omission by Mr. LEWIS of the references to the original sources of the measures given. Not even a list of the papers consulted in the preparation of the work is printed, so that it is not possible to say, except by comparison with recent astronomical literature, to just what date published measures are included. It is probable that space considerations account for this omission, for it must of course be kept in mind that the present work treats of more than twice as many stars as are contained in BURNHAM'S Catalogue and approximately five times as many as were discovered by OTTO STRUVE; and that as these stars have been known longer, and are for the most part easier objects to measure, the published measures and discussions relating to them bear even larger ratios to those on the β and OΣ stars.

To the present reviewer, however, this omission constitutes a fundamental defect in Mr. LEWIS'S volume, regarded as a work of reference, for any one who wishes to investigate the motion in a given stellar system will desire to consult the original measures in order that he may weight them and combine them in such manner as in his judgment will give the most reliable solution. For the β stars and the OΣ stars he will find a convenient and complete guide to all published data to a definite date in the volumes referred to above, but in the case of the Σ stars he will be no better off in this respect after consulting Mr. LEWIS'S volume than he was before.

To illustrate the fact that no two computers are likely to combine their data in quite the same way, and also to show that the present volume is not exhaustive in point of containing all published measures, I have copied in parallel columns the angle measures of 70 *Ophiuchi* = Σ *2272* for the years 1891 and 1892, as given by LEWIS and as given by DOBERCK in his recent discussion of the orbit in *Astronomische Nachrichten*, No. 4115.

The slight differences in the data common to the two lists are undoubtedly due to differences in the manner of combining

the individual measures, and they illustrate my point that every computer will wish to consult the original data when undertaking the discussion of a double-star orbit.

Lewis. Date.	Angle.	Observer.	Doberck. Date.	Angle.
1891.53	327°.8	...Tarrant.....	1891.53	327°.8
.54	328 .3	...Maw.....	.54	328 .3
.55	325 .1	....H. Struve.....		
.56	327 .6	...Hall.....	.56	327 .5
		...Collins.....	.56	329 .3
.58	329 .1	...Schur.....	.58	328 .8
		...Schiaparelli...	.60	328 .5
.61	326 .1	...Bigourdan.....	.65	326 .7
		....Knorre.....	.64	327 .2
1892.37	321 .9	...Burnham[1].....	1892.37	321 .9
		...Collins.....	.41	320 .5
.42	319 .6	...Knorre.....		
.49	321 .7	.. Maw.	.49	321 .7
.54	321 .1	...Comstock.....	.57	321 .3
.65	319 .1	...Bigourdan.....	.62	319 .3
.63	321 .2	...Tarrant.....	.63	321 .2
.64	321 .0	...Schur.....	.64	320 .7
.65	320 .3	...Schiaparelli...	.65	320 .3
		...Glasenapp.....	.68	317 .5
		...Gledhill.....	.69	311 .8

As for the incompleteness of the data shown by this comparison, it is unfortunately true that other stars also show it. For example, in the case of δ *Equulei*, Mr. Lewis has overlooked, among other measures, Hussey's fine series[2] made with the 36-inch telescope on ten nights each in the critical years 1901 and 1902. Nor are all the data given concerning published orbits. The reader, for instance, would infer that Doberck had computed two distinct orbits of η *Cassiopeiæ*, and only two, whereas in his discussion (*A. N.* 3743) he gives a series of six sets of elliptic elements and states that No. VI "must be considered as the definitive orbit, so far." Mr. Lewis quotes Nos. IV and V of those orbits, but curiously enough omits No. VI. Again Doolittle's[3] orbit of Σ 518 has apparently been entirely overlooked.

[1] In Doberck's article this measure is erroneously attributed to Bigourdan.

[2] See these *Publications*, Vol. XIV, p. 197.

[3] *Proceedings American Philosophical Society*, Vol. XLII, 1903, p. 170.

It is quite unnecessary to multiply such instances, for, after all, they only affect the value of the work as a reference-book, and it is very possible that the author did not plan his work as a reference-book in any sense, but considered it wholly as a discussion of the motions of the Σ stars based on their measures since discovery and of the problems these motions suggest. It is certain, at any rate, that in this discussion lies the value of the work. Every star has evidently been carefully studied, and however opinions may differ as to the validity of the conclusions reached in individual cases, Mr. LEWIS's arguments are always interesting and suggestive and his judgments entitled to consideration.

Features of special value are his study of the proper motions, and his analysis of the meridian observations of such stars as ε *Hydræ*, ζ *Herculis*, and γ *Virginis*, which throw new light on the peculiarities shown by the micrometer measures. Another commendable feature is the inclusion of data relating to the spectra of the brighter stars.

New orbits are given for nineteen binary stars, eighteen of which were computed by Mr. LEWIS himself and one by Mr. BOWYER. Four of these pairs are not Σ stars, strictly speaking, but are due to the discovery by OTTO STRUVE, ALVAN CLARK, and BURNHAM that one member of a wide Struve pair is itself a close double star. Orbits had been previously completed for all of these pairs, and in most cases the new elements do not differ greatly from the former ones. For many other pairs Mr. LEWIS gives the apparent ellipse that, in his judgment, best represents the observed motion, but wisely takes a conservative view of the value of these orbits, remarking, for example, that the figure is to be regarded only as a possible representation, or that, while it satisfies the law of equal areas fairly well, too much reliance must not be placed on it.

One of the most suggestive parts of the whole book is Mr. LEWIS's discussion in the Introduction of the distribution of double stars in space. Curves are given showing the distribution of the stars in ARGELANDER's D. M. and of the Σ stars. It is seen from the marked similarity of the two curves, with their strong maxima in the plane of the Milky Way, that the distribution of the Σ stars in the sky follows very closely the distribution of the stars in general. But when the Σ stars

are divided into classes based on relative motion, and the resulting groups compared, very different curves appear. Thus the curve showing the ratio in each hour of right ascension of the relatively fixed pairs to pairs in relative motion rises to a maximum in the early hours of right ascension and has an equally well-marked minimum in the hours from 16 to 21. A very similar curve results when the fixed physical pairs (i. e. those whose components have a common motion through space but show no relative change) are compared with those showing orbital motion. Mr. LEWIS thinks that "no systematic effect due to observational conditions strongly influenced this curve [No. 3] which deals, not with the absolute number of pairs observed, but with the proportion of pairs of one class to pairs of another class." But he suggests a very simple cause that might alter the proportion of fixed and moving pairs in different parts of the sky—namely, that the stars in certain regions are, as a whole, more distant from us than in others. We cannot follow his analysis of the distribution of the Σ stars based on this conception, but must content ourselves with stating his conclusion, which is that it "seems to show that the stars around us form a universe very much the shape of an egg, and that we are not situated in the center." The longer diameter of this "egg" lies in a line from 3^h to 13^h R. A., and the Earth is nearest the surface of it in about 19^h R. A. He estimates the longer diameter as roughly equivalent to 600 light years, and the smaller to 300 light years. "Professor SEELIGER," he says, "considers the Milky Way in its nearest parts as distant from us some 4,400 light years. If so, the Milky Way evidently lies quite beyond the systems here discussed. It may also be accepted that while the region 3^h R. A. to 12^h R. A. is intrinsically richer in double stars, it is comparatively poor in pairs showing relative motion."

Whether we accept these conclusions or not, their presentation in this form will doubtless stimulate further investigation of the most important problems connected with the study of double stars. To the present reviewer it appears doubtful whether the Σ stars furnish adequate data for their solution, and it was precisely with the object of supplying such data that the systematic survey of the sky for the discovery of new

double stars was undertaken at the Lick Observatory some years ago. When this is completed, as it is likely to be within two or three years, it is the writer's hope to be able to discuss these questions anew.

R. G. AITKEN.

September 15, 1906.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD AT THE LICK OBSERVATORY, SEPTEMBER 29, 1906, AT 8 P. M.

Vice-President CAMPBELL presided. The following members were duly elected:—

Mrs. CHARLES D. BLANEY.....	Stevens Creek Road, San Jose, Cal.
Mr. E. A. FATH.....	Lick Observatory, Mt. Hamilton, Cal.
Miss ESTELLE GLANCY.....	Students' Observatory, Berkeley, Cal.
Mr. JAMES E. GOULD.....	Conant Hall, Harvard University, Cambridge, Mass.
Rev. G. HEREDIA.....	Director of the Observatory, Puebla, Mexico.
Mr. JOHN L. HOWARD.....	340 Steuart St., San Francisco, Cal.
Mr. WILLIAM A. MAGEE.....	5 Montgomery St., San Francisco, Cal.
Mr. GEORGE FREDERICK PADDOCK	Casilla 1219, Santiago, Chile.
Rev. GEORGE M. SEARLE, C. S. P.	St. Paul's Church, 415 W. 59th St., New York, N. Y.
Dr. ARTHUR B. TURNER.....	Montclair, N. J.
Mr. R. J. TYSON.....	Seaboard Bank, 24 Market St., San Francisco, Cal.

Adjourned.

No formal meeting of the Society was held on September 29, 1906.

OFFICERS OF THE SOCIETY.

Mr. A. O. Leuschner ..... *President*
Mr. Chas. S. Cushing ..... *First Vice-President*
Mr. A. H. Babcock ..... *Second Vice-President*
Mr. W. W. Campbell ..... *Third Vice-President*
Mr. R. G. Aitken }
Mr. F. R. Ziel } ..... *Secretaries*
Mr. F. R. Ziel ..... *Treasurer*

Board of Directors Messrs. Aitken, Babcock, Burckhalter, Campbell, Crocker, Cushing, Hale, Leuschner, Richardson, Spreckels, Ziel.

Finance Committee—Messrs. Cushing, Crocker, Richardson.

Committee on Publication—Messrs. Aitken, Townley, Newkirk.

Library Committee—Mr. von Geldern, Mr. Richardson, Mrs. Schild.

Committee on the Comet-Medal — Messrs. Campbell (ex-officio), Burckhalter, Perrine.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 806 Franklin Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 806 Franklin Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," 806 Franklin Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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A REVIEW OF CERTAIN RESEARCHES ON RADIO-ACTIVITY THAT HAVE A BEARING UPON ASTRONOMICAL QUESTIONS.

BY BURT L. NEWKIRK.

Since the discovery of the penetrating property of the X rays by Professor RÖNTGEN in 1895 the progress of certain branches of physical science has been so rapid that one not actually engaged in the work of investigation along these particular lines can scarcely keep pace with the new theories and discoveries. The most striking advances are a result of the study of radio-activity; the series of facts brought to light by this study being of so extraordinary a character as almost to bewilder the student. Just how much of a revolution in physical theory they will effect cannot now be estimated, but the prospect is such that no person interested in any branch of physical science can afford to be uninformed with regard to these discoveries. Their special interest to students of astronomy lies in their bearing upon theories of the constitution of matter and the relation between matter and electrical energy. The light which the study of the phenomena of radio-activity is throwing upon these questions must influence very materially theories of cosmological processes. It being obviously impossible to give anything like a complete account of this subject within the limits of such a paper, only those points are noticed that have a more or less direct bearing upon astronomical problems.

For the information contained in the following pages I am chiefly indebted to the two editions of Professor RUTHERFORD'S "Radio-activity," though other sources have been made use of, some of which are indicated by exact references.

Radio-activity is a property possessed by certain substances of emitting a so-called radiation which affects a photographic plate, and is detectable in other ways. The only substances which have so far been found to possess the property of radio-activity to any considerable extent are uranium, thorium, actinium, and radium, and certain "disintegration products" of these substances. There is, however, some experimental evidence in favor of the view that many substances are more or less radio-active.

Radium is the most active of the four substances mentioned above. If an unexposed photographic plate, protected from light by inclosure in a box, be left for a short time in the neighborhood of a small amount of radium and then removed and developed, it is found to be fogged.

Certain substances show fluorescence when brought into the presence of radium. I have seen an observer locate a small amount of radium which was behind a closed door by moving a screen of fluorescing substance about until it glowed, when opposite the radium. Electrically charged bodies in air or in any other gas are rapidly discharged if there is a small quantity of radium in the neighborhood. Exposure of the human skin to the radiation produces irritation, and, where the exposure is excessive, severe inflammation which is very slow in healing. Radium also has the property of warming itself and the receptacle which contains it above the temperature of the surrounding atmosphere. The other three substances mentioned as possessing radio-active properties are less active than radium, but they undoubtedly possess all of these properties in a less marked degree.

The resemblance of these effects to the effects produced by the X rays at once suggests the theory that they are due to a radiation from the active substances similar in character to the X rays. It will be remembered that the latter will penetrate substances opaque to ordinary light, fog a photographic plate, discharge electrically charged bodies, produce fluorescence in certain salts, and cause irritation of the human cuticle.

A remarkable series of experiments performed in the Cavendish Laboratory by Professor J. J. THOMSON and his students led to the theory regarding the origin and nature of the X rays that is at present generally accepted. According to it,

the cathode rays consist of a stream of "electrons," each having a mass of about one thousandth of the mass of the hydrogen atom and carrying a certain definite charge of electricity, known as the "ionic charge," being the charge carried by an ion of unit valency in electrolysis. The X rays are thought to be ether-pulses set in motion when the electrons meet with any obstacle which retards them in their flight, as, for example, the glass walls of the vacuum-tube.

Investigation of the radiations from radium and the other active substances has brought out the fact that three different kinds of "radiations" are emitted. They are known as the α, β, and γ rays, respectively. The α rays consist of a stream of particles having a mass of the order of magnitude of the hydrogen atom, and carrying a positive charge when observed in their flight through a gas. Recent observation indicates that these α particles are without an electric charge when ejected from the active substance, but acquire their positive charge upon collision with the atoms or molecules of the gas through which they fly.[1]

The β rays consist of a stream of negatively charged electrons,—that is, particles whose mass is about a thousandth of the mass of the hydrogen atom.

The γ rays are thought to be ether-pulses similar to the X rays, but differing from them in a certain quality of intensity. When a Crookes tube in which the vacuum is of an exceedingly high order is used to produce X rays, exceptionally penetrating rays, called "hard" rays, are produced. The γ rays bear a closer resemblance to the hard X rays than to the ordinary, or soft, X rays, and it seems probable that the difference between the γ rays and the X rays is only in this quality of "hardness."

A gram of radium in radio-active equilibrium emits about 2.5×10^{11} α particles per second with velocities varying between ten and thirteen thousand miles per second.[2] The heat equivalent of the kinetic energy of this stream of particles is about 100 gram calories per hour. This is roughly the amount of heat necessary to melt one gram of ice. A gram of radium generates sufficient heat by the bombardment of its α particles to melt its own weight of ice each hour.

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[1] *Nature*, August 2, 1906, p. 316. [2] *Phil. Mag.*, October, 1906, p. 769.

The number of β particles emitted by a gram of radium per second is estimated to be 7×10^{10}, and they are emitted at velocities of from 35,000 to 190,000 miles per second. Their mass is so small that the kinetic energy of their flight is small as compared with that of the stream of α particles.

The γ rays are thought to arise from the acceleration of the β particle somewhat as the X rays are produced by the cathode particle as stated above. They are supposed to travel with the velocity of light.

It seems to be quite certainly established that the energy developed by radium, due to the bombardment of the α particles, is not derived from any external source, but is contained in the radium atoms. Accompanying this discharge of energy there is supposed to occur a disintegration of the radium atom. This disintegration occurs at such a rate that half of any given quantity of radium would disintegrate in 2,600 years,[1] a half of the remainder in the next 2,600 years, and so on. Thus, if a gram of pure radium were put into a closed tube and examined at the end of a period of 5,200 years, it would be found that the tube contained one fourth of a gram of radium and such of the products of the disintegration of the other three quarters of a gram as had not escaped through the walls of the tube. All this time the radium in the tube would be radiating heat sufficient to melt its own weight of ice each hour.

It is clear from the preceding statements that the atoms of the radio-active substances must be regarded as storehouses of comparatively enormous amounts of energy. About two pounds of radium would give off in the course of its disintegration sufficient energy to drive one of our largest ocean liners across the Atlantic at record-breaking speed.

The analysis of the disintegration products of the radio-active elements is one of the triumphs of modern research. It should be remarked that the claim that an actual disintegration of a *chemical element* takes place has been called in question by Lord KELVIN, and has been the subject of an animated controversy among English physicists and chemists.[2] The result of the discussion was simply to bring out the fact that we may either regard the radio-active substances as

[1] RUTHERFORD, *Phil. Mag.*, October, 1906, p. 367.

[2] See letter by SODDY, *Nature*, September 20, 1906, p. 516.

unstable chemically complex substances or as unstable elements. It is the propriety of calling these substances elements and not the fact of disintegration that has been called in question.

The disintegration theory offers very simple and direct explanations of a multitude of observed phenomena, and I shall proceed to give an account of the observed facts of the "disintegration" of the radio-active substances as interpreted by the theory advanced by RUTHERFORD and SODDY.

The four radio-active substances—uranium, thorium, actinium, and radium—disintegrate so slowly (radium being by far the most rapid of the four) that it is difficult, and in most cases impossible, to collect a sufficiently large amount of the disintegration products to make an analysis of them by chemical or spectroscopic methods. The property by which their presence is detected is their radio-activity (for most of the disintegration products are themselves radio-active). It will be remembered that one of the properties of radio-active substances is the ability to discharge an electrified body in its neighborhood. If a current of air is drawn through a tube containing radium and passed into a charged electroscope, the electroscope is quickly discharged. This suggests the theory that radium gives off a gaseous disintegration product, itself radio-active, which is carried with the air-current into the electroscope. Other tests confirm this theory. Fortunately enough of this "radium emanation" can be collected to make a chemical examination possible. It is found to be an inert gas of the argon group and of high atomic weight.

The walls of a vessel in which the radium emanation is allowed to disintegrate are found to become radio-active, and it has been ascertained that the product of disintegration of the emanation is a solid, called "radium A," which condenses on the walls of the vessel containing the emanation, and that this radium A disintegrates, forming another substance—radium B. The four substances—radium, the emanation, radium A, and radium B—possess distinct physical and chemical properties. Three are solid, the fourth a gas. Radium A and B can be separated by certain chemical processes, but cannot be collected in sufficient quantities for chemical examination. Three other substances, each having its distinctive

chemical properties, are quite certainly "disintegration products" of radium. These are designated as radium D, E, and F, respectively.

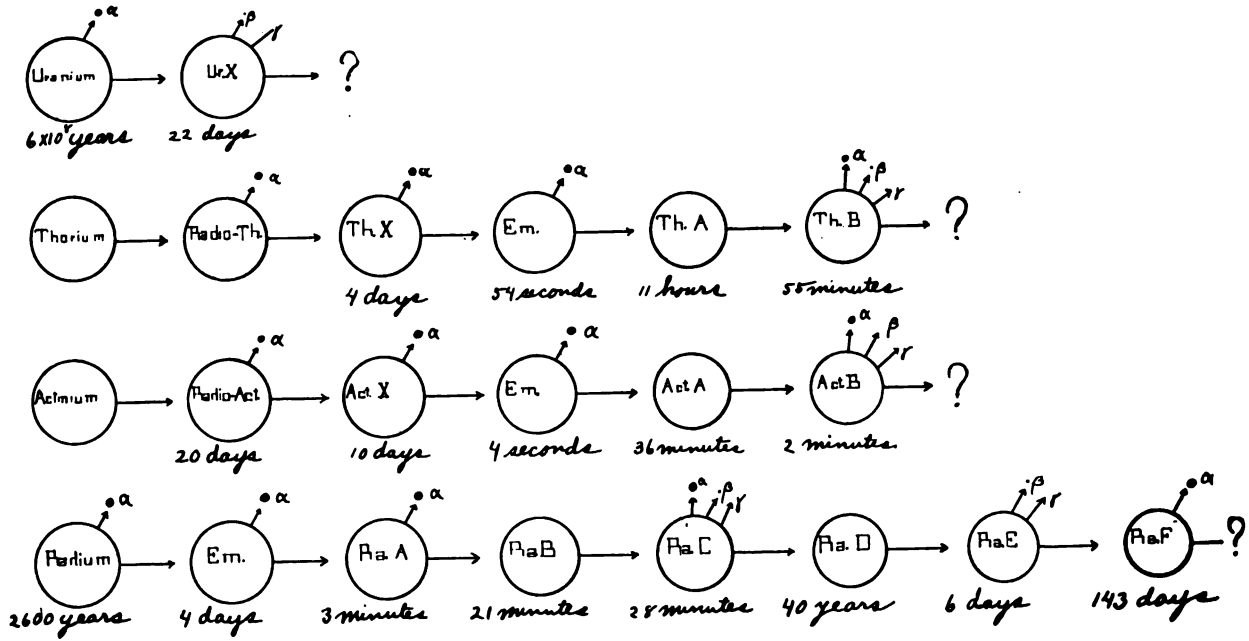
Most of the progress in the analysis of the disintegration products is due to experiments suggested by the hypothesis that each active substance disintegrates as a function of the time according to a simple law similar to the one stated above for radium. There is a certain period of time (2,600 years in the case of radium) during which the activity of a given amount of the active substance decays to half value. Where the period of decay to half value amounts to only a few hours or minutes, as it does in the case of most of the disintegration products, it is possible, by making observations on the activity of a product at intervals during its decay, and plotting the activity against the time, to tell whether the active substance under examination is simple or not. In this way it was discovered that the active matter deposited after the decay of the radium emanation was not a simple substance, but a combination of two substances, which it was afterwards found possible to separate by chemical methods.

According to the foregoing, each of the disintegration products is characterized by its period of decay. They are further characterized by the type of radiation given off. Some emit α rays only, some β and γ rays only (these two kinds of rays never occur separately), some emit α, β, and γ rays, and others seem to be rayless changes. A table is given on the opposite page exhibiting the results of the analysis of the disintegration of the four substances previously mentioned. It is a copy of the one given in the second edition of RUTHERFORD'S "Radio-activity" with the few changes necessary to bring it up to the date of this writing.[1]

It is not possible to measure directly the mass of the α particle but the ratio $(\frac{e}{m})$ of the charge to the mass of the particle can be measured. The value of $\frac{e}{m}$ seems to be the same for α particles from all of the radio-active substances and their disintegration products.[2] If it is assumed that the charge e is the ionic charge, the mass of the α particle is about twice

[1] HAHN, *Phil. Mag.*, July, 1906, pp. 92, 93; LEVIN, *Phil. Mag.*, September, 1906, p. 188; RUTHERFORD, *Phil. Mag.*, October, 1906, p. 367.

[2] RUTHERFORD, Phil. Mag., October, 1906, p. 364.


Uranium
α
UrX
β
γ
?
6×10⁹ years
22 days
Thorium
Radio-Th.
Th X
Em.
Th. A
Th. B
4 days
54 seconds
11 hours
55 minutes
Actinium
Radio-Act
Act X
Em
Act A
Act B
20 days
10 days
4 seconds
36 minutes
2 minutes
Radium
Em.
Ra. A
RaB
Ra C
Ra. D
Ra E
Ra F
2600 years
4 days
3 minutes
21 minutes
28 minutes
40 years
6 days
143 days

that of the hydrogen atom. If it be assumed that the charge is twice the ionic charge, the mass of the α particle must be regarded as four times that of the hydrogen atom. This is the mass of the helium atom, and the presence of helium in minerals containing the radio-active substances, together with evidence of the growth of helium in vessels containing radium emanation, suggests the hypothesis that the α particle is an atom of helium. There is considerable evidence, derived from a study of the relative amounts of uranium and radium found in old minerals, that radium is a disintegration product of uranium, with probably other products intervening.[1]

A remarkable characteristic of these radio-active disintegrations is their almost total independence of the physical or chemical state of the disintegrating substance. The decay proceeds at the same rate at the temperature of liquid air as it does at the temperature of the Bunsen flame. Only one exception to this rule has been discovered. The rate of decay of radium C is somewhat accelerated for temperatures between 630° and 1300° centigrade. Chemical compounds of an active substance are active and the degree of activity indicates that the active substance is suffering transformation, as if it were in an uncombined state. The various devices by which ordinary chemical reactions are accelerated or retarded fail to produce any effect upon the rate of decay of a radio-active substance, except in the above-mentioned case of radium C.

It has been known for some years that the air above the land contains a radio-active substance. No observations for radio-activity seem to have been made on air collected in midocean. This radio-activity of the air is due to the presence in it of the emanations of radium and thorium. Air drawn from the soil is always more or less radio-active, and radium is widely distributed through the Earth's crust.

The question has been raised whether all matter is not radio-active to a greater or less extent. Experiments have been made which seem to favor this view, but it is impossible to make sure that the observed radio-activity is not due to the presence in the substance under investigation of minute quantities of one of the four substances whose radio-activity is recognized, or

[1] For evidence of the production of radium from actinium, see letter by BOLTWOOD, *Nature*, November 15, 1906, p. 54.

of their decomposition products. It is a well-known fact that many substances emit negatively charged particles when illuminated with ultra-violet light, and metallic sodium does so without this stimulus. However, this phenomenon differs essentially from that of radio-activity, particularly in the dependence of the activity upon the excitation of the ultra-violet light.

The "rayless" changes which some of the disintegration products of the radio-active elements are known to undergo (e. g. Th. A to Th. B) suggest the suspicion that ordinary matter may be disintegrating in such a way that the process escapes observation. The rayless changes of the disintegration products are detectable only because they are transition stages between two active products. Ordinary matter may be undergoing a "rayless" transformation which escapes observation. The products of such decay would be expected to have physical and chemical properties very different from the parent substance, but they would probably be produced in such minute quantities as to escape detection by chemical means. The effectiveness of the α rays in producing the phenomena of ionization and fluorescence, and in affecting the photographic plate, by means of which their presence is detected, depends upon the velocity of the α particles. α particles traveling at a velocity only slightly less than that which characterizes the α-ray particles of active substances produce no observable effect. The velocities with which the α particles are emitted is not the same for all active substances, but, on the contrary, each active substance or disintegration product which emits α rays, emits them with a certain definite velocity characteristic of itself. It has been suggested that the "rayless" changes are accompanied by the emission of α particles at velocities below the critical value, which produce no observable effect. The fact that the radio-active substances have the heaviest atomic weights of all known chemical elements lends credence to the idea that their disintegration may be more violent than that of other substances. The suggestion that other substances than those known to be radio-active are undergoing a rayless disintegration accompanied by the expulsion of α particles seems therefore not an unreasonable one.

The age of the Earth has been computed by Lord KELVIN

and others from the rate at which the temperature increases with depth below the surface and on the assumption that the Earth was once a molten mass which has cooled by radiation. The age of the Sun has also been computed on the assumption that it has contracted from a nebula of indefinite extent, transforming the original potential energy of its rarified state into heat and light. The earlier computations led to a maximum age for the Earth and the Sun of something like a hundred million years, and later computations based on data of this sort tend to place the maximum ages at a lower figure. Geological and biological evidences indicate that the Earth must have had a stable crust for several hundred million years. A study of the amount of radium in the soil in many localities and of the radio-activity of the air which penetrates the soil has yielded evidence of the existence of an amount of radium in the Earth's crust sufficient to account for the temperature gradient, observed near the surface, by the heating effect which accompanies its decay. It would seem, then, that the method of calculating the Earth's age from the temperature gradient near the surface is not capable of yielding reliable results. Computations based upon the amount of helium found in a couple of old minerals gave four hundred million years as the age of the minerals.

The age of the Sun depends also upon the amount of energy available for radiation. If we were certain that there is no considerable source of energy supply other than the potential energy of an original diffuse state, as was formerly supposed to be the case, it would be easy to set an upper limit to the period of time during which it can have radiated any considerable amount of heat and light. If, however, the immense stores of energy suspected of existing in the atom are available as sources of heat and light, it would be impossible at present to estimate the life of the Sun either past or future. The existence in the Sun of helium, which is supposed to be a product of the decomposition of radium, makes it seem probable that radium is present also.

The discovery of the existence of electrons having a mass only one thousandth as great as the lightest known atom, and the study of the phenomena of radio-activity have led to theories and speculations regarding the constitution of matter.

Many observed facts indicate that there is an intimate relation between electricity and matter. A portion at least, and possibly all, of the apparent mass of the β particle or electron is due to the charge of negative electricity which it carries. A charge of electricity moving at a high velocity (less than the velocity of light, but of the same order of magnitude) possesses inertia which increases the apparent mass of the charged body. KAUFMANN found that the total mass of the electron might be regarded as due to the charge of electricity.[1] In other words, an electron may be a "disembodied" charge of electricity.

The apparent decomposition of the atoms of radio-active substances and ejection of apparently identical α particles from different elements has tended to strengthen the feeling that has been very general among scientific men for many years, that the atoms are of composite structure, and probably all built up out of some single material. It has been suggested that the electron is the unit of which the atoms are aggregations, characterized by differences in the number and arrangement or motions of the electrons composing them.

One consequence of such an electrical constitution of matter would be a strong presumption in favor of the instability of the atom. Motion of the electrons within the atom implies a certain amount of acceleration of the charged particles, which would result in a radiation of energy and probably in the final disruption of the atom in some way not yet fully worked out.[2]

Another consequence of the theory would be to make matter appear as a form of electricity, and two substances formerly thought of as entirely distinct and different would be found to be but two phases of one substance.

The mass of an electron depends upon the velocity with which it is moving, and any change in its velocity produces a corresponding change in its mass. If the atoms of matter are composed of moving electrons, their mass depends upon the velocity of motion of these electrons, and will be changed by an increase or decrease of their energy of motion. It is not at all unreasonable to suppose, on the other hand, that ordinary forms of energy may pass into that form of energy which con-

[1] *Phys. Zeitschr.* 4, No. 1 b., p. 54 (1902).

[2] Sir OLIVER LODGE, *Nature*, June 11, 1903, p. 128.

stitutes the mass of an atom of matter. Thus the law of the conservation of matter and the law of the conservation of energy would be superseded by a single law of the conservation of matter and energy, it being recognized that matter and energy are but two forms of one thing, just as it is now recognized that heat, which was formerly supposed to be a substance, is in fact a form of energy.

The theories of cosmogony which have been generally accepted up to the present time recognize in the life history of the solar system only a non-periodic process. The continual radiation of heat and light by the Sun is dissipating its original limited store of potential energy, and this supply of energy cannot last at the present rate of expenditure for more than ten or twenty million years longer. At the end of that time, further contraction by the force of gravity being impossible, the Sun is expected to become cold and dark, as the Moon is at the present day. Other suns are supposed to be going through this same process of energy dissipation, so that the whole universe is tending toward a state of uniform distribution of energy and consequent stagnation of all activity. This tendency would not be changed by the occurrence of collisions of celestial bodies, though the conversion of the kinetic energy of their motion into potential energy capable of being transformed into heat and light would prolong the process. Even if through the occurrence of collisions all of the kinetic and potential energy of the universe were made available as heat and light, it would, according to current theories, in the course of time be dissipated and a state of stagnation ensue.

It is assumed also that at the beginning of the process matter existed in a diffuse state, as in the nebulæ, and that at the end of the process it will exist only in a very concentrated state. It is as if the cosmological mechanism were wound up and set in motion to run until it should run down by the dissipation of energy and concentration of matter.

There is something in the human understanding that refuses to accept such a theory as final, and insists that there must be some rejuvenating process supplementing the one just described and making the whole a periodic process repeating itself indefinitely.

If it shall appear that the atoms of ordinary matter are the

storehouses of such comparatively enormous amounts of energy as appear to reside in the atoms of radio-active substances, the total amount of all other forms of energy in the universe will dwindle into insignificance in comparison with the energy of atoms of matter; and if it shall also appear that this energy is capable of being transformed into the radiant energy of heat and light or potential energy, cosmological theory will have to reckon mainly with the transformation of this atomic energy.

Radio-active substances emit the α particles with velocities of something like ten thousand miles per second, which would easily carry the particles beyond the gravitational control of any known mass or system of masses, and amply suffices for the scattering of matter which must form a part of any rejuvenating process that is to complete the cosmological cycle. No theory has been offered to explain the process by means of which the flying particles are recombined into atoms of ordinary matter.[1] That such a transformation should occur under the conditions of tremendous pressure and high temperature obtaining in the interior of a sun would not seem unreasonable; it may be, however, that electric and magnetic forces have more influence upon this transformation than pressure and temperature have. A serious objection to such an hypothesis would appear in the very great amount of energy which would be absorbed in the process, and for which the potential energy of the original diffuse condition of the mass would be totally inadequate.

It would be useless to venture any prediction as to the extent to which the study of the phenomena of radio-activity is destined to modify current theories of the physical and chemical sciences. The questions under investigation are, however, of such vital importance to cosmological theory that this alone is sufficient to command for these researches the intense interest of followers of astronomical science.

LICK OBSERVATORY, November 12, 1906.

[1] In a note on the "Electric Equilibrium of the Sun" (*Proceedings of the Royal Society of London*, Vol. 73, p. 496), ARRHENIUS concludes that electrons traveling through space with a velocity of the order of magnitude of the velocity of light would be drawn into the stars by the attraction of the charge of positive electricity which there seems reason to believe the latter possess.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1907.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter.	Jan. 7,	6h 47m	A.M.	Last Quarter.	Feb. 5,	4h 52m	P.M.
New Moon....	" 13,	9 57	P.M.	New Moon....	" 12,	9 43	A.M.
First Quarter..	" 21,	12 42	A.M.	First Quarter.	" 19,	8 35	P.M.
Full Moon....	" 29,	5 45	A.M.	Full Moon....	" 27,	10 23	P.M.

The Earth is in perihelion on January 1st, shortly before midnight.

There will be two eclipses during January. The first is a *total eclipse of the Sun* January 13-14th, invisible in the United States, as it occurs during the night. The path of totality is wholly confined to the eastern hemisphere, extending from a point north of the eastern end of the Black Sea southeast, and then northeast, ending in Siberia. The duration of totality is short,—less than two and a half minutes at the point where it is a maximum. The second is a *partial eclipse of the Moon* in the early morning of January 29th. The beginning only is visible in the eastern part of the United States. The end of the eclipse occurs shortly before sunrise in the extreme western part of the country, and the whole eclipse may be seen, except the penumbral portion. The principal phases are as follows, Pacific time:—

Moon enters penumbra,	January 29,	2h	46m	A.M.
Moon enters shadow,	" "	4	6	A.M.
Middle of the eclipse,	" "	5	38	A.M.
Moon leaves shadow,	" "	7	10	A.M.
Moon leaves penumbra,	" "	8	30	A.M.

At the time of maximum obscuration about seven tenths of the Moon's diameter is eclipsed.

Mercury is a morning star throughout January, having passed greatest west elongation on December 18th. It rises about an hour and a quarter before sunrise on January 1st, and may be seen in the early morning twilight for a few days, but it soon draws too near the Sun to be seen. It passes superior conjunction with the Sun on February 2d and becomes an

evening star, but sets less than one hour after sunset until the last third of the month. At the end of February it has nearly reached its greatest east elongation, and sets about an hour and a half after sunset. It may then be easily seen in the evening twilight on a clear night. The elongation is not as great as the average greatest, as the planet is in perihelion on February 27th, only two or three days before the time of greatest elongation. *Mercury* is in conjunction with *Saturn*, passing 1° 40′ north of the latter on the night of February 20th. Both planets then set about an hour after sunset, but they may possibly be seen if the weather is unusually clear.

Venus is a morning star, rising about three hours before sunrise throughout January. The interval shortens to less than two hours and one half by the end of February. It reaches its greatest west elongation (46° 53′) on the evening of February 8th, and begins to slowly approach the Sun. It attains its greatest brightness on January 4th, and for some weeks about that time it will be bright enough to be seen in full sunlight.

Mars rises at about half-past 2 on January 1st and about an hour earlier by the end of February. During the two months it moves about 34° eastward and 8° southward through *Libra* and *Scorpio*. On January 8th it passes less than 1° north of the third-magnitude star *α Librœ*, on February 8th it passes south of the third-magnitude star *β Scorpii* at an apparent distance of less than half the Moon's diameter, and on February 18th it passes about 5° north of the first-magnitude star *Antares*, *α Scorpii*. It is now approaching the Earth quite rapidly, the distance diminishing more than fifty millions of miles during January and February. Its brightness nearly doubles from January 1st to February 28th, and at the latter date is about four times as great as it was at its minimum in the summer of 1906. It will be brighter than the average first-magnitude star at the end of February; but even then it will be only one ninth as bright as at the coming opposition next July.

Jupiter passed opposition with the Sun on December 28th, and is therefore in fine position for observation, being above the horizon most of the night. It sets a little before 5 A.M. on February 1st, and a little before 3 A.M. on February 28th.

It is in *Gemini,* and moves westward about 6° with a continually diminishing motion until February 25th.

Saturn is in the southwestern sky in the evening, setting about half-past 9 on January 1st, and only half an hour after sunset at the end of February. It will then, and for a fortnight before, be too near the Sun for a naked-eye view. As seen in a telescope, the rings are closing up very rapidly, and they will be out of sight when *Saturn* reappears after conjunction with the Sun.

Uranus was in conjunction with the Sun on December 30th and became a morning star, but remains too close for naked-eye view until late in February. It is in the constellation *Sagittarius,* and moves about 3° westward north of the stars in the handle end of the "milk-dipper" group.

Neptune is in opposition with the Sun on January 2d. It is in *Gemini,* east of *Jupiter,* but is far too faint to be seen without a telescope.

(FIFTY-THIRD) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to W. R. BROOKS, astronomer, Geneva, New York, for his discovery of an unexpected comet on January 26, 1906.

Committee of the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
C. D. PERRINE.

SAN FRANCISCO, November 19, 1906.

(FIFTY-FOURTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to A. KOPFF, astronomer, Heidelberg, Germany, for his discovery of an unexpected comet on March 3, 1906.

Committee of the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
C. D. PERRINE.

SAN FRANCISCO, November 19, 1906.

(FIFTY-FIFTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to D. Ross, astronomer, Melbourne, Australia, for his discovery of an unexpected comet on March 17, 1906. Committee of the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
C. D. PERRINE.

SAN FRANCISCO, November 19, 1906.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Orbit of the Spectroscopic Binary λ *Andromedæ*.[1]

The binary character of this star was announced by Campbell in the *Astrophysical Journal* in 1899, and plates taken later in the same year showed the period to be $20^d.5$. The first eighteen plates were taken with the original Mills spectrograph, $H\gamma$ central, and the other thirty-eight with the remounted Mills, 4500 central. Definitive measurements seemed to show a discrepancy between the series taken with the first Mills spectrograph and the plates taken with the second Mills, and a complete series was secured with the new instrument in order to determine the nature of the disagreement. Least-square solutions were made of each series by the method of Lehmann-Filhés, and following are the elements of the orbit resulting from each solution:—

	Old Series (1899).		New Series (1905).	
U	$= 20^d.538$		$20^d.546$	
μ	$= 17°.529$	± 0.014	$17°.521$	± 0.006
T	$=$ J.D. 2414571.81	± 0.037	2416683.46	± 0.39
ω	$= 336°.2$	± 7.6	301.0	± 7.6
K	$= 6.48^{km}$	± 0.19	7.07	± 0.16
e	$= 0.132$	± 0.038	0.086	± 0.018
V	$= +6.34^{km}$	± 0.13	7.43^{km}	± 0.10
$a \sin i$	$= 1.810000^{km}$		$1.990\,000^{km}$	
Probable error of single observation		$\pm 0.50^{km}$	$\pm 0.51^{km}$	

A series of plates taken after the lapse of a few years would no doubt establish or disprove the reality of the change in elements. Such a series should be taken in a single cycle of $20^d.5$ if possible, in order to eliminate the effects of changing

[1] For the full discussion of the orbit of this star see Lick Observatory *Bulletin*, No. 104.

elements and error in period. The discrepancy of the two sets of elements, if established, will no doubt be found to be due to a third body. The variation in ω and V is probably real, as it is five times the probable error in the former case, and check plates taken along with the star plates of both series show no systematic difference. K. BURNS.

November 21, 1906.

THE RADIAL MOTIONS OF *POLARIS*.

The motions of *Polaris* in the line of sight, as affected by its two invisible companions, have been carefully observed at frequent intervals since the Mills spectrograph established in 1899 that this star is a triple system. The binary system, consisting of the bright star and one of the unseen companions, has a well-established period of revolution, 3 days, 23 hours, 14 minutes; but the period of this binary system and the second unseen body remains unknown. Only an undetermined fraction of one revolution has been described since the beginning of my work on this star in 1896. The observed minimum values of the bright component's velocities are as follows, subject to slight corrections when the final reductions are made:—

1896.9	-20.7^{km} per second.
99.8	-14.2
1900.6	-14.6
01.4	-16.3
02.6	-16.8
03.0	-17.2
03.7	-17.8
04.5	-18.5
06.5	-19.8

Two sets of observations, consisting of eight or ten spectrograms each, secured in 1905, have not yet been reduced.

It appears from these figures that the position of minimum is gradually working its way down to that of 1896.9. The value -20.7^{km} furnished by the earliest observations is probably near one end of the range of velocities. The cycle of changes will not be complete until the values reach -20.7^{km} on the down or up curve described at 1896.9. The period may safely be said to exceed ten years, and is probably less than twenty years. W. W. CAMPBELL.

SEVEN NEW SPECTROSCOPIC BINARIES.

Observations made with the Mills spectrograph in the course of the regular observing programme show that the following stars have variable velocities in the line of sight.

1 *Geminorum* ($\alpha = 5^h\ 58^m.0$; $\delta = +23°\ 16'$).

The spectrum is type H. Measures of four plates taken in 1903, 1905, and 1906 give a total range of about 8^{km}. The variation in its radial velocity was discovered by Mr. MOORE.

B. A. C. 5890 = D. C. 7579 ($\alpha = 17^h\ 21^m.3$; $\delta = -5°\ 0'$).

The star is an F type, with broad lines. Both spectra are visible. The ratio of their intensities is about two to one, although the behavior of all lines is not the same in this respect. Its period is probably short. The variable velocity and doubling of spectrum were discovered by Mr. BURNS. From his observations of the variations from coincidence of the two spectra it seems probable that the masses of the two stars are not very different.

δ *Sagittæ* ($\alpha = 19^h\ 42^m.9$; $\delta = +18°\ 17'$).

The spectral type is M. The observed range of velocities is about 14^{km}. Its binary character was suspected by Mr. CAMPBELL in 1901 and confirmed by the recent measures.

o^2 *Cygni* ($\alpha = 20^h\ 12^m.3$; $\delta = +47°\ 24'$).

Its spectrum is of the H type. The measures of four plates (two taken in 1905, and two in 1906) give a total range of 30^{km}. The variable velocity was discovered by Mr. BURNS.

ϵ *Cygni* ($\alpha = 20^h\ 42^m.1$; $\delta = +33°\ 36'$).

This is a K-type star. The total variation in velocity from seven plates (1896-1906) is about 7^{km}. Its period is probably several years. Its binary character was suspected by Mr. H. D. CURTIS in 1903 and confirmed by the recent measures of Mr. BURNS.

ζ *Cygni* ($\alpha = 21^h\ 8^m.7$; $\delta = +29°\ 49'$).

This star is of the K type. Seven plates (1896-1906) give a total range of 7^{km}. The variable radial velocity was shown by the measures of Messrs. STEBBINS and BURNS.

ι *Capricorni* ($\alpha = 21^h\ 16^m.7$; $\delta = -17°\ 15'$).

The spectrum is H type. The total range in velocity for six plates (1900-1906) is about 9^{km}. Its variable velocity was suspected by Mr. MOORE from the third plate and confirmed by recent measures.

W. W. CAMPBELL.
J. H. MOORE.

LICK OBSERVATORY, November 12, 1906.

NOTE ON SOME SIMPLIFICATIONS IN THE REDUCTION OF STELLAR PHOTOGRAPHS.

A number of accurate methods for the reduction of measures of star photographs exist. Some of these methods require *four* plate-constants to be determined, whereas in others it is necessary to derive *six* constants.

In satellite and asteroid work, where only one or two places are to be derived from each plate, the labor of obtaining these constants is relatively great. This consideration, together with the rapidly increasing number of places which are derived photographically, makes it desirable to simplify the processes as much as possible.

To obtain the accurate position of a star on a plate, four constants, besides a knowledge of the refraction, are necessary, viz.:—

Scale value,

Orientation, and

The right ascension and declination of the center of the plate.

Values for these constants, as near the true ones as possible, are usually assumed and corrections obtained by a least-square adjustment of the residuals derived from a comparison with catalogue stars.

If, instead of taking an *arbitrary* plate-center, we take the *center of gravity* of our *system of comparison-stars,* the corrections to the center become zero, and we have but *two* unknown quantities to determine.

To obtain the rigorously accurate center it is only necessary to apply the mean of the *proper curvature corrections* to the mean of the right ascensions and declinations of the comparison-stars.

The adoption of the above center shortens the solution for the remaining two constants by reducing some of the coeffi-

cients to zero. A number of simple checks can also be introduced.

If the curvature corrections are derived from arguments depending upon the *intersection of the optical axis on the plate*, as origin, the above treatment is rigorous in the sense in which that term is now applied to the reduction of stellar photographs.

Lick Observatory *Bulletin* No. 102 contains the necessary formulæ for the reduction in the above manner.

These formulæ are intended for the reduction of measures over a field 2° or less square, whose center lies between declinations of $-75°$ and $-75°$. In the immediate regions of the poles this method, which is based on the well-known four-constant method of JACOBY, does not apply.

A full account of the method has been prepared, which, together with general tables of curvature corrections, auxiliary tables to facilitate the computation of refraction constants, etc., will appear later as a publication of the Lick Observatory.

MT. HAMILTON, CAL., November 16, 1906. C. D. PERRINE.

NOVA AQUILÆ No. 2.

Several photometric observations of *Nova Aquilæ* have been added this year to my series published in Numbers 104, 105, and 106 of these *Publications*. The 36-inch refractor was used, but it has not been available for the purpose on good nights.

A preliminary discussion of the measures of the comparison-stars *x*, *f*, *g*, and *k* leads to the values: *x*, $12^m.01$; *f*, $13^m.63$; *g*, $15^m.0$; *k*, $15^m.0$. The co-ordinates of *k* referred to the *Nova* are: $\Delta\alpha$, $-0^s.4$; $\Delta\delta$, $-18''$.

The magnitudes derived for *Nova Aquilæ* are given in the column "*Nova*":—

G. M. T. 1906.	Settings on *Nova*.	Comparison-stars.	*Nova*.	Weight.	Remarks.
June $14^d.95$	12	*g k*	$14^m.6$	2	Fair conditions.
Aug. 18 .77	8	*d e*	15 .2	2	Fair conditions.
Oct. 19 .67	3	*d e*	15 .2	1½	Poor conditions; obs. incomplete.

An observation was attempted on October 23d in moonlight and poor atmospheric conditions. All the faint com-

parison-stars were measured, but the *Nova* was glimpsed only at a single favorable moment. Its magnitude was probably about 15½ on this date. JAMES D. MADDRILL.

November, 1906.

COMETS *g* AND *h* 1906.

Comet *g* was discovered by H. THIELE, of Copenhagen, Denmark, on the night of November 10th. The first measure secured at the Lick Observatory was on the following night, November 11th. At that time the comet was easily visible in a 3-inch telescope. It has since become somewhat brighter, but at no time has it been seen with the naked eye. At the present time it is as near the Earth as it ever will be, about 58 million miles. It will gradually leave us, and on January 20, 1907, it will be 1.2 times as far from the Earth as the latter is from the Sun, and three tenths as bright as at its discovery. The following parabolic elements were computed by Dr. AITKEN and the writer:—

$$T = 1906,\ \text{Nov. } 21.14697\ \text{G. M. T.}$$
$$\left.\begin{aligned} \omega &= 8^\circ\ 33'\ 48''.9 \\ \Omega &= 84\ \ 54\ \ 48\ .3 \\ i &= 56\ \ 27\ \ 41\ .5 \end{aligned}\right\} 1906.0$$
$$\log q = 0.084400$$

Comet *h* is a very faint comet, which was discovered photographically by Mr. J. H. METCALF, of Taunton, Mass., on the night of November 14th. Notice of the discovery was received at the Lick Observatory on November 17th, and the comet observed that night in R. A. $4^h\ 4^m$ and Decl. south $3^\circ\ 1'.5$. The comet, on the night of November 17th, was with difficulty visible in a 3-inch telescope, but since that time it has not been so bright. The comet is round, about 30″ in diameter, and has a stellar nucleus of the 13th magnitude. It is moving slowly, the principal motion being toward the south. On November 24th its approximate position was R. A. $4^h\ 2^m$; Decl. south $4^\circ\ 21'$. No orbit has been computed up to this time.[1]

November 27, 1906. E. A. FATH.

[1] Elements computed by Miss LAMSON, of the Naval Observatory, Washington, D. C., were received on December 6, 1906.—EDITORS.

A New Variable Star.

On the night of September 26, 1906, in the course of my survey for new double stars, I examined the star B. D. $+51°.3676$ and found that it was fainter than 9.0 magnitude, though marked 7.8 in the B. D. As an examination of the published lists of variable stars failed to show this star, I called Mr. Maddrill's attention to it, and he has secured the observations given below, which prove beyond doubt that it is a variable, almost certainly of long period. The star is given in two star catalogues, Radcliffe I (epoch 1846.9) and Harvard A. G. (epoch 1873.6), and is there rated as 7.0 and 7.5 magnitude respectively.

The star's position is:—

$23^h\ 32^m\ \ 3^s.0;\ +51°\ \ 27'.8\ \ (1855.0)$
$23\ \ 34\ \ 11.55;\ +51\ \ 42\ \ 31''.3\ \ (1900.0)$

R. G. Aitken.

Photometer Observations of B. D. $+51°.3676$.

Photometric observations of the star have been secured on several nights, at the suggestion of Dr. Aitken. On each night the suspected variable star was compared with two stars, *a* and *b*, with the Rumford [1] wedge photometer.

To eliminate or check changes in the artificial star or in the transparency of the sky, the order of observation was in each case: *v a v b v b v a v*, three or four settings of the wedge—with one or two more, if discordant—being made on each star in turn. The same combination of shade-glasses was used each night. The Moon happened to be above the horizon during each observation.

The details of observation will be given later in a Lick Observatory *Bulletin*. It seems sufficient for the present to state that the conditions were not good in general but that concordant results were obtained, as shown in the following self-explanatory tables:—

COMPARISON-STARS.

Star.	B. D.	Adopted Mag.	Authority.
a	$+51°.3655$	$7^m.02$	Harvard Photometric Durchmusterung.
b	$+51\ .3670$	$8\ .88$	Mean of my nine measures.

[1] See these *Publications*, No. 103; or the more extended description in Lick Observatory *Bulletin* No. 83.

OBSERVATIONS.

Obs.	Date, 1906.	Julian Day, G. M. T.	Observed Magnitude. *a*	*b*	*v*	Weight.
1	Sept. 28	2417482.75	$7^m.02$	$8^m.88$	$9^m.12$	1
2	Oct. 3	87.68	7 .09	8 .81	9 .11	⅓
3	" 5	89.81	7 .02	8 .88	9 .17	⅔
4	" 26	7510.69	7 .01	8 .89	9 .46	1
5	" 29	13.81	7 .00	8 .90	9 .37	1
6	" 31	15.67	7 .01	8 .89	9 .36	⅔
7	Nov. 5	20.78	6 .95	8 .95	9 .42	⅔
8	" 26	41.73	7 .08	8 .82	9 .63	⅔
9	" 27	42.73	7 .00	8 .90	9 .54	⅔

NOTE.—*v*, the variable, is in effect compared with the *mean* of *a* and *b*; the error of observation of the constant stars is equally distributed between them.

JAMES D. MADDRILL.

NOTE ON THE CHILE EARTHQUAKE OF AUGUST 16TH.

The cable messages received through the Department of State and directly from Dr. CURTIS, at Mt. Hamilton on August 23d and 24th, respectively, brought the comforting messages that the Mills Observatory was undamaged and Dr. CURTIS and family and Mr. PADDOCK were safe. Dr. CURTIS's letter of confirmation, written August 17th, reached me on October 20th; no mails were despatched until a fortnight after the catastrophe, and the letter was fifty-one days en route.

Dr. CURTIS states that "there were two hard shocks separated by an interval of a few seconds, the total duration of the severe motion being 4^m 50^s. I started counting the seconds to time it; but changed to a sudden wish to see the lamps put out, and ended in a rush for the rain-drenched patio. The din was very great and all around could be heard the shrieks of the people. . . . A corner of our garden-wall was down, the rear (adobe) wall of our house was nearly all down, there was a five-inch crack at the ceiling where the side wall of the dining-room had nearly gone down, and there was fallen plaster and stucco everywhere. Nearly all of Santiago slept out of doors that night, in spite of the rain. . . . The after-effects of the 'quake have been remarkably persistent. The earth was literally in continuous movement for four hours

after the heavy shock, during all of which time the lamps kept quivering, with only an occasional intermission of rarely over thirty seconds. Every once in a while came a heavier temblor that sent us hurrying to the doors. After midnight [the great terremoto was at 8:00 P.M.] there were longer intervals when there was no movement, but sharp shocks came at 2:00 and 4:00 A.M. This has kept up all day." The total number of after-shocks up to the 20th was over one hundred, and they continued to be numerous for many days following.

The damages at the observatory were limited to a little broken glassware in the dark-room, and to the cracking of a stone wall in the outbuilding used as watchman's and storage quarters. The road up to the observatory was filled in places with rock-slides, and in other places the road-bed slipped down the mountain. The instruments, dome, and main buildings were uninjured.

I hope that we may regard the severe ordeals through which the Lick Observatory passed on April 18th and the Mills Observatory on August 16th as entirely exceptional.

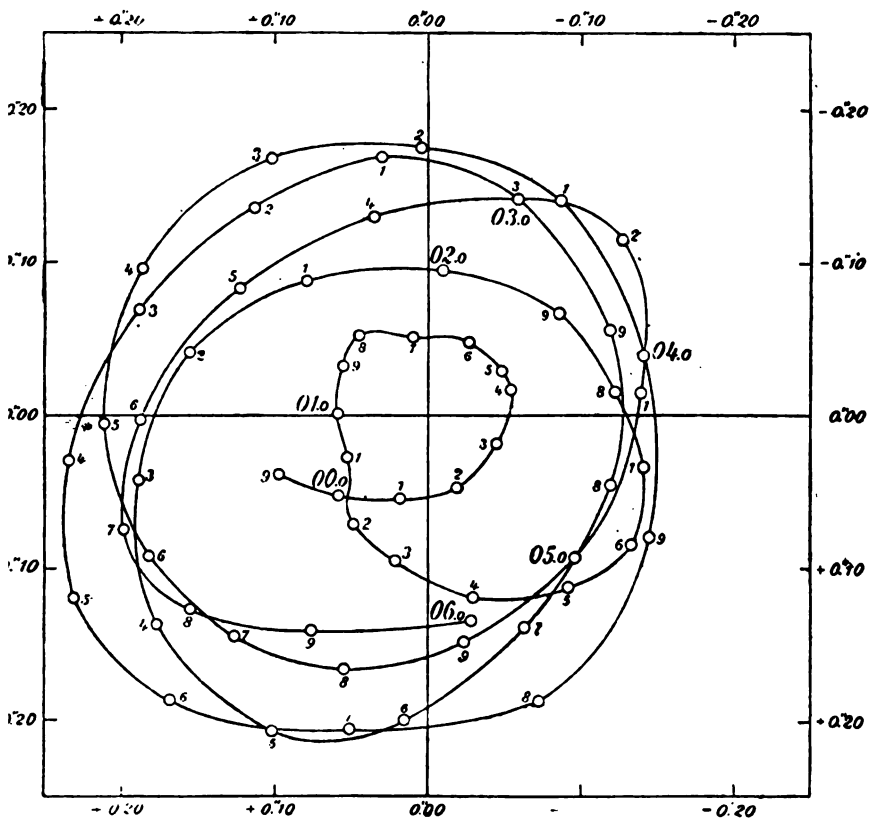
W. W. CAMPBELL.

ERRATUM.

In No. 108 of these *Publications,* under the figure opposite page 212, *for* "these," *read* "the three."

GENERAL NOTES.

Variation of Latitude.—From the annual report of the Central Bureau of the International Geodetic Association, it appears that the number of latitude determinations made at



the various stations established for the purpose of determining the variation of latitude gives a total for 1905 of 11,477, distributed as indicated in the first column of the tabulation given below. The total number of observations made from the time the stations were established, fall of 1899, to the beginning of

1906 is 75.111. distributed as indicated in the second column of the table.

	[illegible]	Total
At Mizusawa	1.569	10.033
Tschardjui	1.739	11.044
Carloforte	2.653	19.651
Gaithersburg	1.409	10.787
Cincinnati	1.527	9.565
Ukiah	2.560	14.031

Provisional results for the latitude work of 1905 have been published by Professor ALBRECHT in the *Astronomische Nachrichten* No. 4121. The amplitude of the polar motion continued to decrease during the year. The motion of the Earth's north pole, from 1899.9 to 1906.0, is represented in the accompanying figure taken from the number of the *Nachrichten* mentioned above.

Volume II of the "Resultate des Internationalen Breitendienstes" appeared recently under the authorship of TH. ALBRECHT and B. WANACH. The volume contains all of the observations made at the six latitude stations during the years 1902, 1903, and 1904, together with the definitive results deduced from the observations. It is hoped at no very distant date to give a more extended account of the contents of this volume.

The Detroit Observatory.—The department of astronomy at the University of Michigan is being reorganized under the direction of Professor W. J. HUSSEY, who was elected to the professorship of astronomy and directorship of the Detroit Observatory last year. The residence of the Director has been enlarged and remodeled, the observatory building changed somewhat, and all the instruments are being overhauled in the observatory instrument-shop. The Regents of the University have also appropriated money for the purchase of a 36-inch reflector, to be used for photographic and spectroscopic work. The glass has been ordered through the well-known opticians, J. A. BRASHEAR & Co., and designs for the mounting of the glass are being prepared.

It is sincerely to be hoped that the authorities of the University of Michigan will succeed in so restoring and developing the department of astronomy that it may again enjoy the prestige gained under the leadership of BRÜNNOW and WATSON.

Motions of the Inner Planets.—At the recent meeting of the Astronomische Gesellschaft held in Jena, a paper was presented by the president, Professor SEELIGER, in which it was shown that certain hitherto unexplained irregularities in the motions of the inner planets might be produced by the perturbation of the cloud of minute particles existing within the orbit of *Mars,* and to which the zodiacal light is supposed to be due. The following table was given, comparing the changes in the longitudes of perihelion, nodes, and inclinations as computed under certain assumptions regarding the distribution and density of the perturbing swarm with those derived by Professor NEWCOMB from observation. The agreement is seen to be in every case well within the probable error of Professor NEWCOMB'S determination.

		SEELIGER.	NEWCOMB.	
$e\frac{d\Pi}{dt}$	*Mercury*	+ 8.49	+ 8.48	± 0.43
	Venus	+ 0.05	— 0.05	± 0.25
	Earth	+ 0.09	+ 0.10	± 0.13
	Mars	+ 0.56	+ 0.75	± 0.35
$\sin i\frac{d\Omega}{dt}$	*Mercury*	+ 0.62	+ 0.61	± 0.52
	Venus	+ 0.60	+ 0.60	± 0.17
	Mars	+ 0.21	+ 0.03	± 0.22
$\frac{di}{dt}$	*Mercury*	+ 0.49	+ 0.38	± 0.80
	Venus	+ 0.20	+ 0.38	± 0.33
	Mars	— 0.04	— 0.01	± 0.20

No change in the eccentricities would result from the assumed perturbations. Professor NEWCOMB'S values for the observed changes were smaller than their probable errors.

N.

Eros Comparison-Stars.—In the course of an investigation of the observations of stars of reference for the *Eros* campaign, Dr. FRITZ COHN, of Königsberg Observatory, has found evidence of a magnitude equation affecting positions determined photographically. Photographically observed positions from the observatories at Bordeaux, Catania, Greenwich, and Toulouse show no evidence of magnitude equation, but those from the observatories at Helsingfors, Northfield, Paris, and San Fernando show a well-marked tendency in this direction.

The observations of the Algiers Observatory had been discarded on account of large discrepancies depending on magnitude, but it was supposed that the other photographic positions were not affected by this source of error. Mr. COHN finds evidence that the magnitude equation depends upon the hour-angle at which the exposures were made, which further complicates the situation, from the point of view of the *Eros* reductions, and at the same time throws light on possible sources of error to be guarded against in stellar parallax investigations and other photographic determinations of position which call for a high degree of accuracy. N.

The Structure and Evolution of the Stars.—Professor F. W. DYSON, M. A., F. R. S. (Chair of Astronomy), took for the subject of his inaugural address "The Recent Progress of Astronomy." About fifty years ago astronomy seemed to have come to a standstill. The great investigations of the law of gravitation as explaining the movements of the planets were in the main completed. Observational astronomy did not seem likely to make new discoveries commensurate with those of HERSCHEL.

The new physical methods of spectrum analysis and photography have now opened new avenues of research, and the lapse of time has made evident movements of the distant fixed stars which were very imperfectly known fifty years ago. A brief résumé was given of four typical lines of modern research—Mr. HILL's Researches on the Theory of the Moon, the Variation of Latitude, Solar Physics, the Present Problems of Sidereal Astronomy. Referring to the discovery of helium in the great nebula of *Orion* by Dr. COPELAND, his predecessor in the Chair of Astronomy, Professor DYSON explained that quite recently new importance had been given to this discovery. Helium was produced by the disintegration of earlier molecular forms, and the question propounded by Miss CLERKE, "Where do the nebulæ get their helium from?" suggested that nebulæ were expelled from stars, and were not the basis from which stars were formed. Astronomical research into the structure and evolution of the stars was of equal interest with the physical research into the structure and evolution of the atom.—*Taken from the Scotsman.*

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD AT HEARST HALL, BERKELEY, NOVEMBER 24, 1906, AT 7:45 P.M.

President LEUSCHNER presided. The following members were duly elected:—

Swarthmore College Library.....Swarthmore, Pa.

Mr. R. J. TYSON was elected to life membership.

The Committee on Publication presented suggestions advocating a revision and changes in the printing of the List of Members; the Committee was authorized to collect the necessary data.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT HEARST HALL, UNIVERSITY OF CALIFORNIA, BERKELEY, ON NOVEMBER 24, 1906, AT 8 P.M.

The meeting was called to order by President LEUSCHNER, who introduced the lecturer of the evening, Dr. T. J. J. SEE, of the Naval Observatory at Mare Island. Dr. SEE then read his paper on "The Cause of Earthquakes and Mountain Formation," illustrating his investigations by a number of lantern-slides.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. A. O. LEUSCHNER ..... *President*
Mr. CHAS. S. CUSHING ..... *First Vice-President*
Mr. A. H. BABCOCK ..... *Second Vice-President*
Mr. W. W. CAMPBELL ..... *Third Vice-President*
Mr. R. G. AITKEN, Mr. F. R. ZIEL ..... *Secretaries*
Mr. F. R. ZIEL ..... *Treasurer*

Board of Directors—Messrs. AITKEN, BABCOCK, BURCKHALTER, CAMPBELL, CROCKER, CUSHING, HALE, LEUSCHNER, RICHARDSON, SPRECKELS, ZIEL.

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Committee on Publication—Messrs. AITKEN, TOWNLEY, NEWKIRK.

Library Committee—Mr. VON GELDERN, Mr. RICHARDSON, Mrs. SCHILD.

Committee on the Comet-Medal—Messrs. CAMPBELL (ex-officio), BURCKHALTER, PERRINE.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 806 Franklin Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 806 Franklin Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," 806 Franklin Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

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(February, April, June, August, October, December.)

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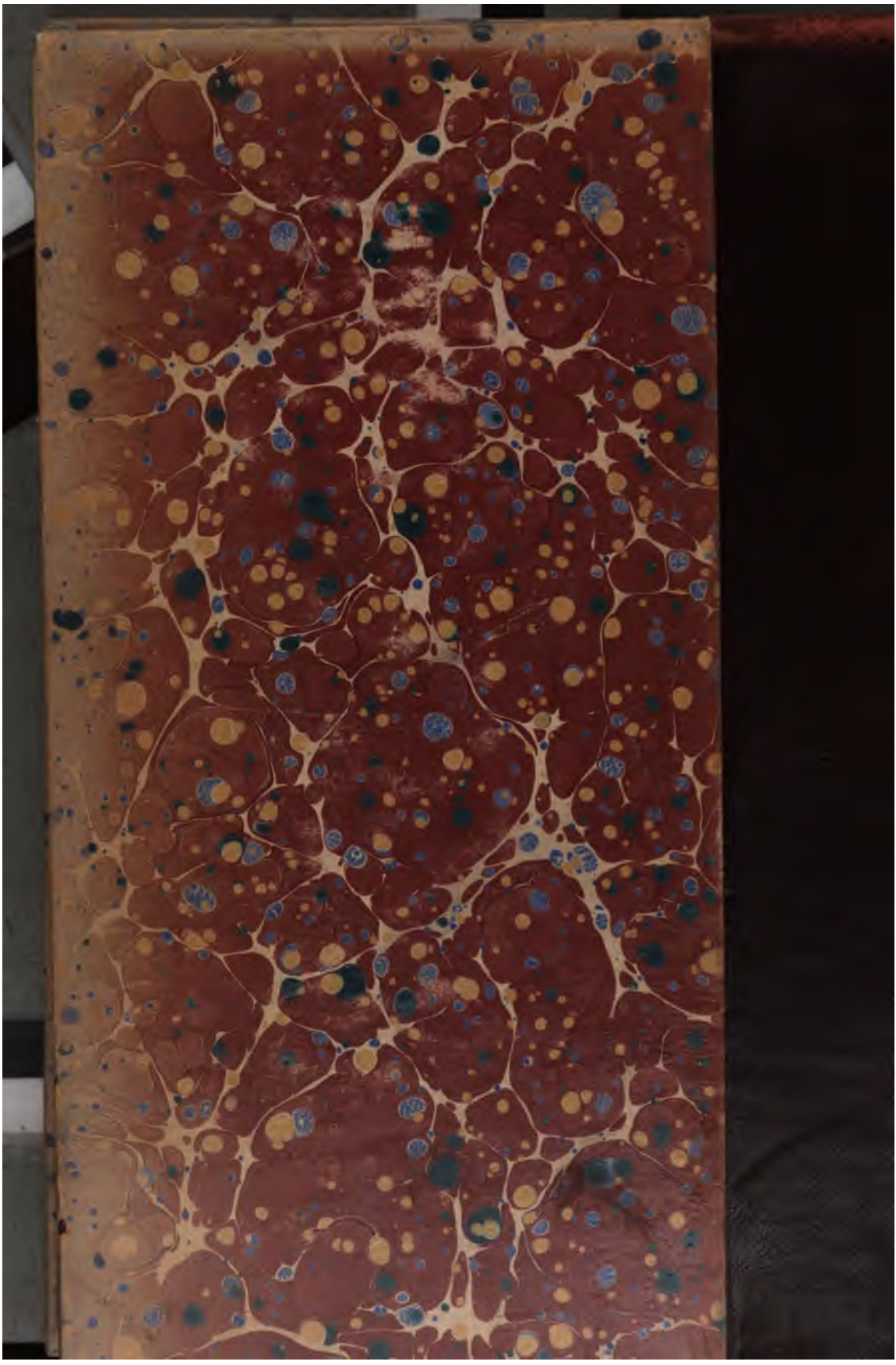
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